Our World Changes

ADVENTURING IN SCIENCE

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Our World Changes

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ADVENTURING IN SCIENCE

EXPLORING OUR WORLD

OUR WORLD CHANGES

USING OUR WORLD

THE WORKBOOKS

DIRECTED ACTIVITIES I
EXPLORING OUR WORLD

DIRECTED ACTIVITIES II
OUR WORLD CHANGES

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USING OUR WORLD

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THIS CHANGING WORLD

The world in which we live is more than a lump of rock in space. It is a fascinating moving picture. It is a moving picture that is never finished because it tells of change that never ends. From the sky above to the rocks below, nothing in the world remains forever the same. From age to age, from year to year, and in some places from minute to minute, everything is busy becoming something different. Everything is in the midst of a journey from what it once was through what it now is to what it will someday be.

The world is more than a fascinating moving picture which we can watch with pleasure. It is a moving picture in which each one of us must play a part. How well we play will depend on how well we understand the story.

The purpose of this book is to help you to understand and enjoy the story of our changing world. It is also to help you to play your part in the story both happily and well.

UNIT ONE

THE CHANGING SKY


Cook Observatory

THE CHANGING SKY

Have you ever walked in the country on a starlit night and wondered about the twinkling points of light above your head? Have you ever wondered how far away the stars are, how large they are, and how they are arranged?

Have you ever wished that you might explore the sky in a rocket and learn what the stars really are?

Have you ever wondered about the sun which shines in the daytime, and about the moon which shines at night?

What are these bright objects, and why do their position and appearance in the heavens forever change?

And where does the earth fit into the mighty picture of the sky?

You do not need a rocket to learn the answers to these questions.

You can learn a great deal about the mysterious dwellers of the sky without ever leaving the earth.

Indeed, you can learn a great deal about them without even leaving your own back yard.

Unit One of this book will try to tell you how.

CHAPTER ONE

What Are the Stars?

GETTING ACQUAINTED WITH THE STARS

The Setting Sun. In New York City a beautiful wide parkway follows the eastern bank of the Hudson River. Any late afternoon or early evening you may see hundreds of people strolling along this drive, seeking rest from the hubbub of a great city. Looking westward over the silver ripples of the river you may see the rocky cliffs which are known as the Palisades. You amble down the parkway with the crowd. The sun is low in the west, a ruddy ball that hangs by some mysterious power in the sky.

As you walk along with your eyes to the west you realize that the scene is changing. The ball of the sun is slowly sinking toward the top of the Palisades. Presently its lower edge is cut away by the cliff. Slowly, but yet rapidly enough so that you can see the movement, the sun disappears behind the Palisades. The sky flames with the glory of the dying day and then slowly fades into the calmer beauty of a starlit night.

You may not fully realize the fact, but you have been watching not only one of the most common but also one of the most mysterious sights in the world. You have turned to the sky from the noisy bustle of the city. You have seen that the sky, like the city, is forever changing. Quiet and majestic though the sky changes are, they never cease.

The daily rising and setting of the sun are among the easiest observations that anyone can make to prove that our world is endlessly changing day by day. The sun is

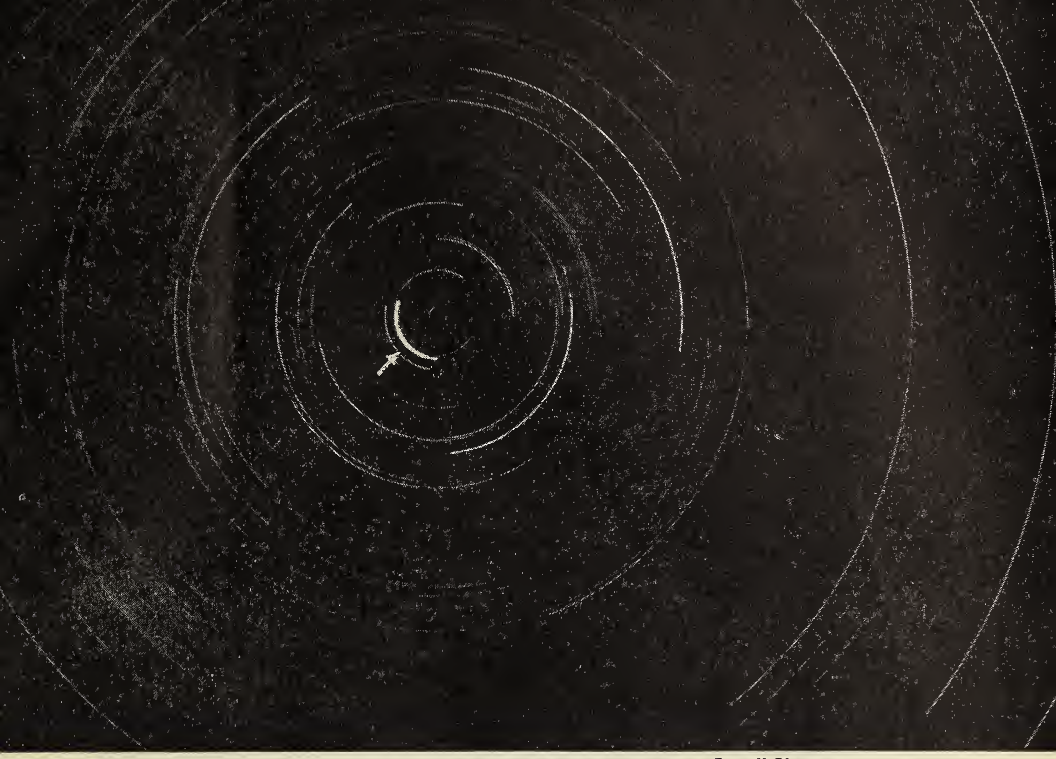
therefore a good place to begin our studies of this changing world. Have you ever wondered why it rises and sets so faithfully every day?

Before we can understand the sun, however, we must understand the stars. *The sun is a typical star.* It is like the millions of other stars that spot the dark night sky with white, excepting that it is much closer to us than any other star. Let us first try to learn in general what the stars really are and then try to understand our particular star, the sun.

The Movement of the Stars. Who has not watched the stars come out in the evening sky! First one appears and then another, then another and another and another. You begin to count them, but as darkness grows deeper you cannot keep up with the army of stars that takes possession of the sky. Instead, you observe that some of the stars are bright and others dim; that some parts of the sky are thick with stars and other parts relatively empty; that some stars are grouped in orderly designs and others just seem to be scattered around. What, you wonder, does all this mean?

Suppose you fix your attention on a particular star or group of stars. A simple observation will teach you an important fact.

Exercise. Select the brightest star you can find in the sky. (Be sure that the one you select twinkles. If it doesn't twinkle, it is not a star but one of the planets, which we shall study in the next chapter.) Carefully mark the position of the star in the sky by viewing it over the corner of a house or the limb of a tree from a definite place on the ground. Return in an hour to the same place and observe the star again. Is the position of the star the same as it was before or has it changed?



Lowell Observatory

This picture of star trails shows that stars seem to move in circles. The arrow points to the trail of the North Star, a circle so small that to the naked eye the star does not seem to change its position at all

This easy observation will prove that *the far-distant stars, like the closer sun, seem to be moving through the sky*. They too are illustrations of change in this changing world.

Star Trails. The change in the position of the stars with reference to the earth goes on very slowly but also very steadily. Watching the change is a little like watching the hands of a clock. It is so slow that you may not be conscious of it unless you observe it over a considerable period of time. A camera, however, can furnish striking proof that the change is taking place.

Exercise. How to prove that the position of the stars with reference to the earth is constantly changing: On a clear night when there is no moon, place a camera on the ground with the lens tilted upward toward the northern sky. Be sure that no electric lights are shining near by. Open the shutter wide and leave it open for two hours. Then close the shutter, remove the film and develop it. If your picture is successful, it will look something like the photograph on page 9.

The curved white lines against the black background of the photograph were made by the light from stars, which would seem to have moved in circles through the sky. These so-called *star trails* are proof of one of the mightiest changes in our changing world.

Exploring the Sky. The sky is a fascinating region, which anyone can explore. On every clear night it spreads its wonders above our heads, inviting us to adventure. But where shall we begin our explorations?

You are probably beginning the study of this unit in September, and you probably live not far from latitude 40 degrees north. The diagram on page 11 will therefore give you a fairly accurate picture of the sky above you about 8 o'clock in the evening. This picture is called *a star map*. It will help you get acquainted with some of the brighter stars, as well as with certain groups, or *constellations*, of stars.

Notice that a curved broken line marked "Overhead" runs across the top of the map. To use the map you must face north and hold the map so that the word "Overhead" is actually over your head, as shown in the drawing below. The position is a bit clumsy and a strain on the neck, but the fun you will get from learning about the stars will be worth the bother.

These stars and constellations are visible in the autumn sky of the Northern Hemisphere

These children are locating stars with the help of a star map

Exercises. During September and October the bright star Vega will be almost directly over your head in the early evening. Locate Vega on the star map and then go outdoors and study the sky with the help of the map, as described in the paragraph above. Locate Vega in the sky. This should not be difficult because there are no other bright stars near it.

After you are sure that you have correctly identified Vega, locate the four stars that make the square of the constellation Pegasus. This star group may be seen about halfway up the sky when Vega is overhead. Locate the famous W of Cassiopeia, a constellation which lies to the north and west of Pegasus. Locate the bright star Arcturus, which lies west of Vega and a little to the north. Locate in similar fashion the Pleiades, the Big Dipper, and the Little Dipper.

Vega, Pegasus, Cassiopeia, Arcturus, the Pleiades, the Big Dipper, and the Little Dipper are among the most striking stars and constellations to be seen in the autumn sky of North America. After you are sure that you can identify them all, go indoors for an hour or two. When you return to your observations, you will find that the sky picture has changed.

Exercise. Locate as many stars and constellations as you can with the help of your star map at 8 o'clock. Return at 10 o'clock and do the same thing. Have the constellations that were high in the sky at 8 o'clock moved toward the west or toward the east? Make a table in which the positions of each star or constellation are described at each period of observation. The following is a sample of what your table should contain.

Star or Constellation	Location at 8 o'clock	Location at 10 o'clock
Vega	A little north of overhead	---?---
Pegasus	East and a little north of Vega, a little above the horizon	---?---
Cassiopeia . . .	A little north and west of Pegasus	---?---
Arcturus	North of Vega near the western horizon	---?---
Pleiades	Far to the northeast and close to the horizon	---?---

You should supply the information for the third column yourself. (*Do not write in the book.*)

The North Star. Study the Big Dipper as shown in the star map on page 11 and observe that two of its stars are labeled "Pointers." If you follow these pointers with your eye, the first star you meet will be the North Star. Though not a very bright star, the North Star is one of the most interesting stars in the sky. *It is the only star whose position does not seem to change.* Every hour of the night and every night of the year the North Star looks down upon us from the same place. Sailors for centuries have used this fact to help them in guiding their ships.

The Milky Way. If there is no moon in the sky and no bright lights close by on the ground, you can see the great band of stars which is known as the Milky Way. Running from north to south in a curved belt across the sky, the Milky Way is so crowded with stars as indeed to look a little like milk. The double-page picture at the beginning of this unit is a photograph of the Milky Way, which was taken through a telescope. Observe the countless pin points of light, some larger and others smaller, some bright and others dim. Each pin point of light is a sun!

Star Maps. So far we have studied only the star map of the northern sky for autumn. Below and on page 15 you will find star maps of the northern sky for winter, spring, and summer. Compare the stars and constellations shown on these maps. They illustrate well the mighty changes that take place in the sky.

Exercise. Look at *A Beginner's Star Book*, by Murphy, or *A Guide to the Constellations*, by Barton and Barton, or *Field Book of the Stars*, by Olcott and Putnam. Any one of these books will help you identify any bright star or constellation in any part of the sky at any time of year.

How the Constellations Got Their Names. All the bright stars and constellations in the sky were known to people ages ago. These people — Egyptians, Chinese, Greeks, and

The northern sky in winter

The northern sky in spring

The northern sky in summer

Romans—gave names to many of these heavenly bodies, and many of the names have come down to us today. The ancient Greeks, in particular, saw all sorts of mythical animals and people in the more striking constellations of stars.

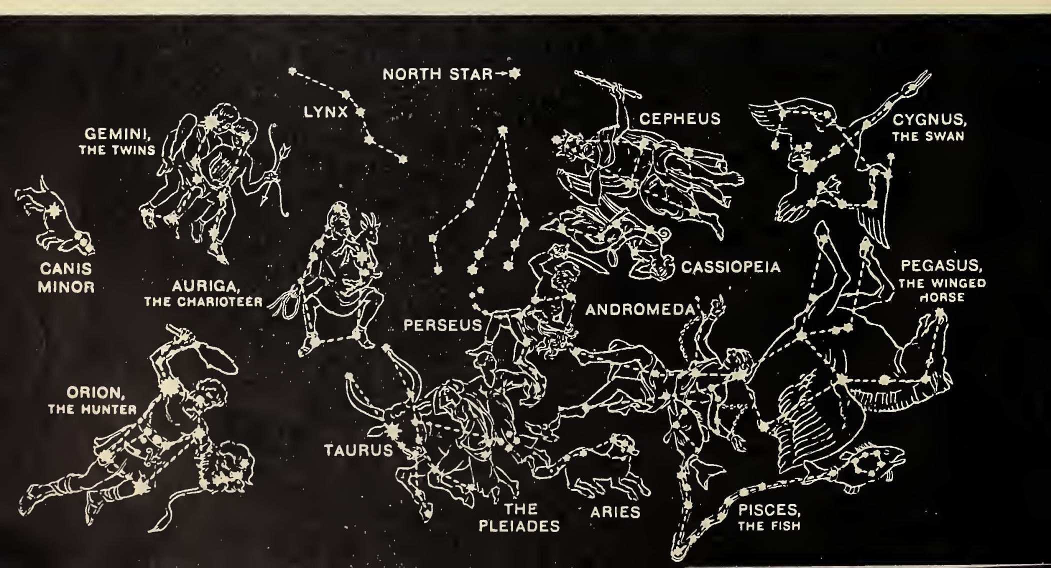
The picture below shows some of these imaginary creatures. The names will not mean much to you unless you read the legends which are attached to them. Once you have learned some of these ancient tales, however, the constellations will become ever so much more fascinating than they were before. You might even be able to see in the sky the strange creatures which the ancients saw!

Exercise. Read some of the ancient tales about the heavens in Williamson's *The Stars through Magic Casements* or Gayley's *Classic Myths* or Johnson's *The Star People.*

WHY THE STARS APPEAR TO MOVE

Science and Myth. The ancient myths make our study of the sky more interesting. They do not, however, answer our questions, What? How? and Why? Only modern science can do that. And modern science about the stars (astronomy) is quite as interesting as the ancient myths.

Here are some of the imaginary creatures which the ancients saw in the sky



It never occurred to the ancients that there might be two ways of explaining the apparent movement of the stars. They believed that the stars move across the sky while the earth stands still. That, to be sure, is the way it *looks*, but is it the way it really *is*? Could not the apparent movement of the stars be explained just as well by assuming that *the earth is turning beneath the stars while the stars stand still*? Let us see.

Observations That Must Be Explained. A few nights of sky-gazing will show you that the North Star does not appear to change its position in the sky. Though the stars and constellations near the North Star seem to move around it, they never sink beneath the horizon. The stars more directly over your head, on the other hand, rise and set like the sun. Furthermore, there are certain stars and constellations which you never see from your position because they are always beneath the horizon.

The facts in the above paragraph would be very hard to explain if the stars were moving in circles round the earth. *They are very easy to explain, however, if the earth is spinning like a top and the stars are standing still.*

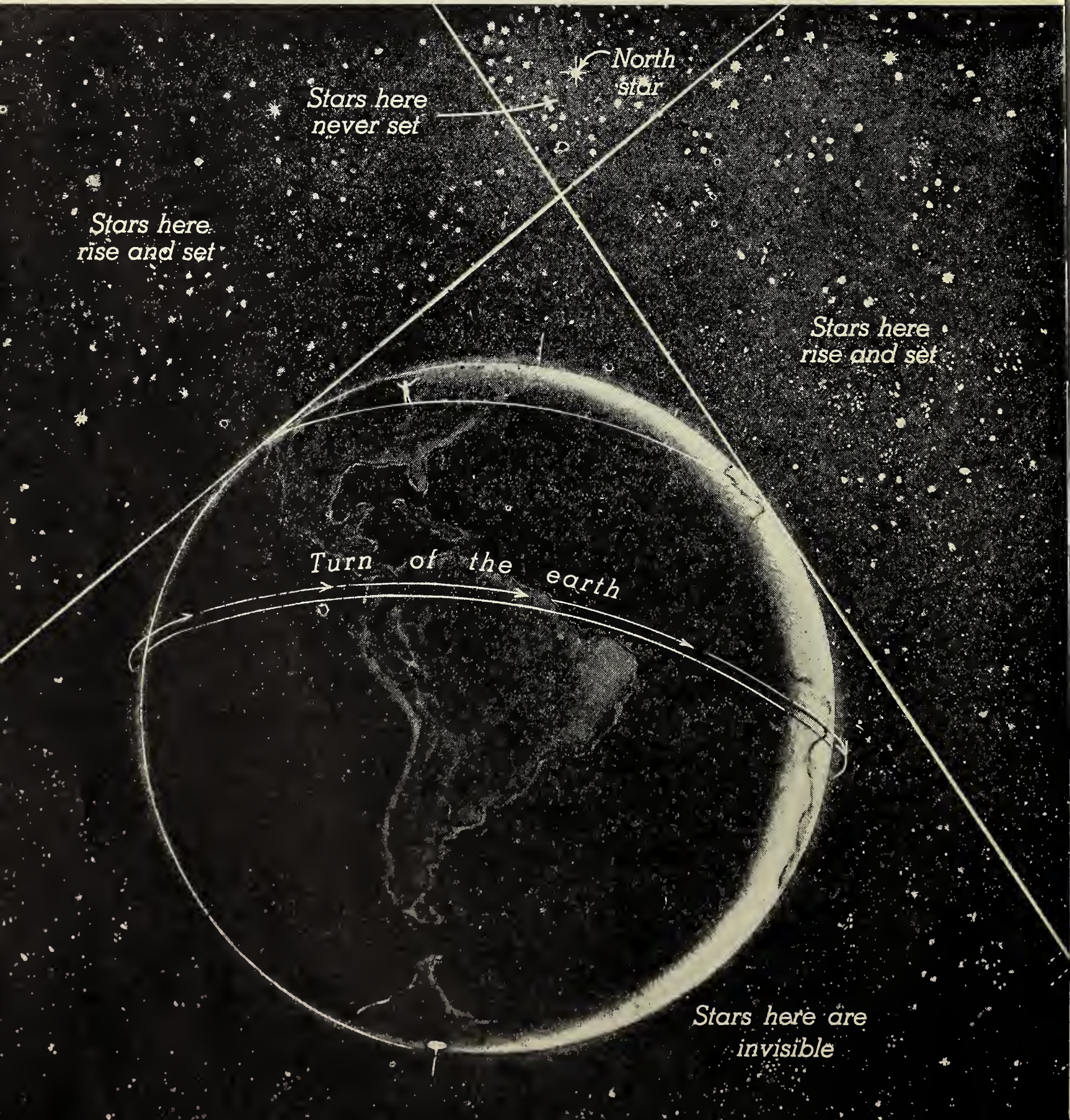
Study the diagram on page 18 very carefully. Suppose that the ball in this picture is the earth, and that it is spinning as shown from left to right (west to east) on an axis that points to the North Star. Suppose you are the person standing on the ball at about the location of Chicago.

As you go round and round, the stars in both the upper left and upper right portions of the diagram will seem to rise in the east and set in the west, just as the sun does. First the stars on one side and then those on the other will *seem* to rise above and sink below the horizon. They *seem* to pass over your head from horizon to horizon just as

fence posts and telegraph poles seem to pass by you when you are traveling in a moving train.

Do you see that because you are well up toward the top of the globe, the stars in the upper central portion of the diagram will always be in view? The bulge of the globe above you is not enough to hide them from your sight at

This diagram explains how the real movement of the earth on its axis causes the apparent movement of the stars



any point in the round-trip journey of the earth on its axis. Do you see that because the axis is pointed toward the North Star, that star will seem not to move; that the stars and constellations near the North Star will seem to move in circles around it? (See star trails on page 9.) Finally, do you see that because of the curve of the globe below you, the stars in the lower portion of the diagram will never be visible so long as you stand near the top of the globe?

Exercise. How to show that the real movement of the earth on its axis causes the apparent movement of the stars: Study an ordinary rotating globe. Put your finger on or near your home town and turn the globe from west to east through a full circle. Imagine that the tip of your finger is you, and that you are watching the stars while the earth turns completely round on its axis. Can you see in your mind's eye that the stars in the sky north of you seem to turn in a circle opposite to the direction in which you are turning, and that they never sink below the horizon? Can you see that the stars directly above you seem to rise and set as the earth turns? Can you see that the stars in the sky above the south pole are never visible to you? If you cannot see these things at once, keep trying. It is good training for one of your most valuable powers—your imagination.

The *real* movement of the earth and the *apparent* movement of the stars are not quite so simple as the diagram on page 18 and the above exercise would make them seem. We shall see later that the earth does not stay in one place in space. It is not only turning each day on its axis, but it is also moving each year in a great circle round the sun. Because of this, different constellations come to view at dif-

ferent seasons of the year, as shown in the star maps on pages 11, 14, and 15.

We shall also see that the stars are not standing absolutely still. They are actually changing their positions somewhat with reference to one another. Many stars, indeed, are rushing through space in various directions at speeds more than 1000 times the speed of the fastest streamlined train on earth.

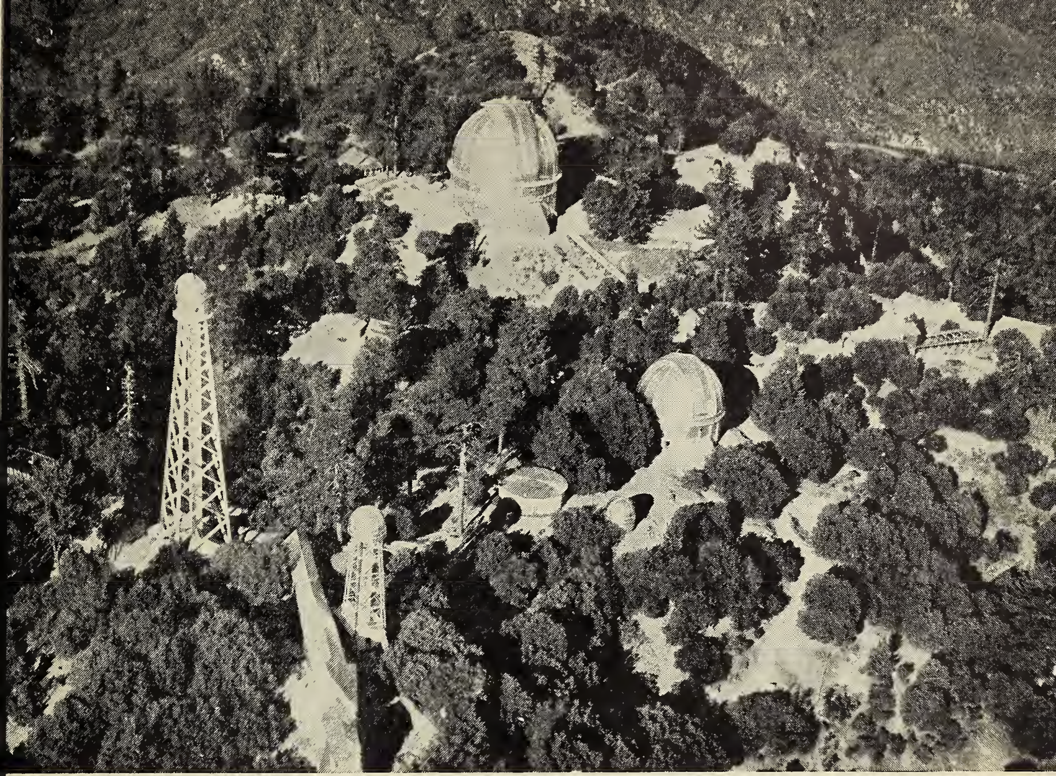
So great, however, are the distances of the stars from one another and from the earth that their movement cannot be seen by an ordinary observer. In other words, modern science has proved beyond any doubt that *the apparent movement of the stars across the sky on any given night is produced by the real movement of the earth on its axis.*

WHAT SCIENTISTS KNOW ABOUT STARS

The Telescope. The photograph on the opposite page shows you a great modern observatory on the top of Mount Wilson, California, where scientists are trying to solve the mysteries of the sky. This observatory and others like it are filled with marvelous instruments for studying the heavens. The most marvelous of these is the telescope. The word "telescope" means "to see afar," and that is exactly what this instrument enables us to do.

The moon, for example, is 238,800 miles from the earth. The best modern telescope brings it, as it were, to within 50 miles of the earth. If New York City were on the moon, we could see it through such a telescope as a small dark spot. We could probably even see a railroad train as a tiny speck moving along the surface!

There is some doubt as to who invented the very first telescope. There is no doubt, however, that the great Italian scientist Galileo (1564–1642) was the first man to



Fairchild Aerial Surveys, Inc.

In these strange buildings on the top of Mount Wilson, California, scientists are studying the worlds beyond our own world

make great discoveries with the help of this instrument. Through a telescope of his own invention (weaker than an ordinary pair of modern field glasses) Galileo was the first human being to see, among other things, the spots on the sun, the mountains on the moon, and four of the eleven moons that circle round the planet Jupiter.

Galileo's telescope consisted of a metal tube with glass lenses at either end. The lens at the outer end acted as an eye which could gather the light and the image of a heavenly body. This image was magnified by the lens at the inner end of the tube. By looking through his telescope Galileo was able to see an enlarged picture of a bright object in the sky which with his naked eye he could not see at all.

Galileo explaining the instrument that was to reveal new worlds to the eyes of men

Before Galileo died he made many telescopes. By enlarging the light-gathering "eyes" of these instruments he was able to enlarge the images of bright heavenly bodies from three to thirty times. Since Galileo's day the scientists of different countries have run a friendly race to see which country could boast the most powerful telescope. The United States leads today because the Mount Wilson Observatory shown on page 21 contains the largest telescope in the world.

On page 25 is a photograph of this great instrument. It does not look much like Galileo's little hand telescope. It is, nevertheless, built on Galileo's plan. The chief difference is that it uses a mirror instead of a lens to catch the light of the stars. The Mount Wilson telescope is now the unrivaled king of all telescopes, but it will not be king much

longer. A telescope *four times as powerful* is almost ready to go into service on Palomar Mountain, California.

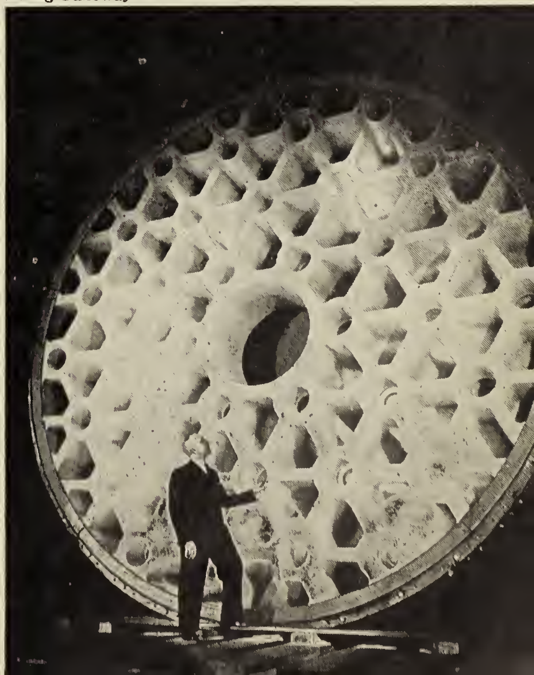
With increase in the power of telescopes there naturally comes increase in our knowledge about the heavens. With his unaided eye the keenest observer on the clearest night can see only a few thousand stars. Through the mighty eye of the Mount Wilson telescope he might see about half a billion!

With every new and more powerful telescope, new and more distant stars have been discovered. The nearly finished telescope on Palomar Mountain will be able to reveal stars which are two hundred billion million miles away! Though this is much farther than any astronomer can see today, no astronomer believes that there will be any scarcity of stars at that vast distance from the earth. There seems to be no end of stars in the sea of space, no bottom to the sea.

The Astronomer's Ruler. Nobody has enough imagination to get any clear idea of the vast spaces between the stars. We might as well say that one star is "blank" miles from another as to say a "billion" miles. Such great figures paralyze the mind. They are also very clumsy to use in speaking about the heavens. The mile is a good measure of distance on our tiny earth, but it gets hopelessly lost in the sky.

This 200-inch mirror was built for the world's greatest telescope, to be located on Palomar Mountain, California

Ewing Galloway

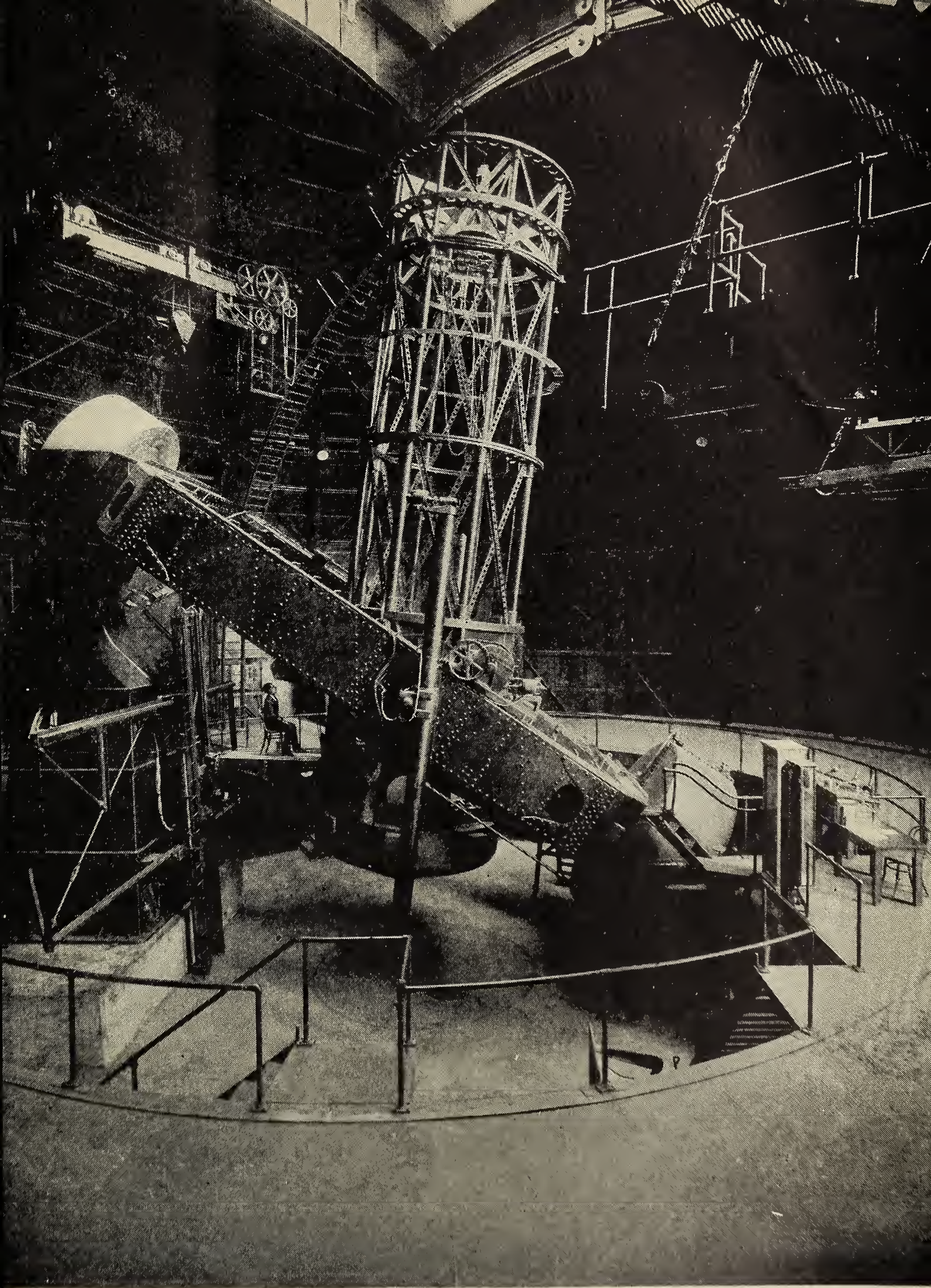


Thanks to brilliant work by Römer, a Danish astronomer of the seventeenth century, and later by Professor Michelson at the University of Chicago, the astronomers have a better ruler than the mile for measuring distances in the sky. By a very clever experiment, Michelson was able to time a beam of light as it traveled back and forth between mirrors from one mountain to another in southern California. He discovered that *light travels at the astonishing speed of about 186,000 miles a second.*

At this speed a beam of light could make seven trips round the earth during one beat of your heart. You can see that if a beam of light traveled steadily for a year, it might get over a considerable piece of sky! Yet that piece of sky (about 6 trillion miles) is the ruler that astronomers find convenient to use in measuring distances between stars.

The ruler is called the *light-year*, which means the distance that light covers in a year while traveling about 186,000 miles a second. Even using such a gigantic ruler, we run into large figures. The nearest visible star to the earth, other than the sun, is about 4½ light-years away. The star Arcturus is 40 light-years from the earth. By a clever device which can change the energy of light into electricity, energy from this star was made to turn on the lights that opened the Century of Progress Exposition in Chicago in 1933. The starlight that did this trick had been rushing through space for 40 years before it was put to use!

When you look at many of the brighter stars in the sky, you see light which has been traveling through space since the fourteenth and fifteenth centuries. When you look at some of the dimmer stars, you see light that began traveling before the birth of Christ. Astronomers believe that some of the more distant stars are hundreds of thousands



Mt. Wilson Observatory

This great telescope at the Mount Wilson Observatory in California is helping to solve the mysteries of the sky

of light-years away. Some may be as much as 1,000,000 light-years away. When you hear people saying, "It's a small world after all," think of this!

The Size of Stars. We have said earlier in this chapter that the sun is a typical star. The sun, however, is a pygmy when compared with some of the giant stars whose size astronomers have been able to measure. The average diameter of stars, judging from those that have been measured, is around 1,000,000 miles. The sun falls short of this average by 140,000 miles. When compared with the great stars Betelgeuse (350,000,000 miles in diameter) and Antares (390,000,000 miles in diameter), the sun is a pygmy indeed.

The Kinds of Stars. Have you ever noticed that some stars have a bluish-white, some a yellowish, and others a reddish color? Astronomers believe that *stars glow because they are made of intensely hot gases.* They believe that the hottest stars are the bluish-white ones, and that as these cool off they fade first to yellow and then to red. There is good reason to believe that space contains many solid "dead" stars which we cannot see because they have lost their heat and their glow.

Exercise. Study the heavens on a clear night and see if you can find examples of bluish, yellowish, and reddish stars.

The Arrangement of the Stars. Your study of the constellations has already shown you that the stars are arranged in definite patterns. In their seeming march across the sky the constellations preserve their orderly arrangement. They keep the same positions *with reference to one another*, marching, as it were, in military order. Similarly the in-

dividual stars do not shift their positions within any particular constellation. Night after night you can find each one in its proper place.

Astronomers have discovered that stars are actually not so "fixed" as they seem to be. Some stars are rushing towards, and others away from, one another at terrific speeds. But *the distances between them are so great that their positions do not appear to change.* We see practically the same arrangement of stars that the ancients saw.

Our Universe. The sun is located in a group of stars which we call our *galaxy*, or *universe.* Astronomers are agreed that our universe is shaped like a watch. We are probably located about halfway between the center and the outer edge.

Our universe is shaped like a watch, and we are located somewhere between the center and the outer edge

Exercise. How to picture in your mind's eye the position of the earth in the universe: Get a watch and imagine that it is an immense group of stars fairly evenly distributed. Imagine yourself inside the watch among the works, about halfway between the place where the hands are attached and the outer edge (see the diagram on page 27). Imagine the stars you would see if you looked up toward the edge that contains the winder. Then imagine the stars you would see if you looked directly toward the face of the watch. In which direction would you see the greater number of stars? This exercise, like the exercise on page 19, is designed to limber up your imagination. Do not give up if at first it seems rather difficult.

When you look toward the Milky Way, you are looking toward the far edge of our universe. You naturally see more stars in that direction than when you look in a direction where our universe is thinner.

Still thinking of our universe as a watch, you can get some idea of its immensity when you know that it takes light traveling at about 186,000 miles a second perhaps 35,000 years to pass directly from the face to the back. It takes light nearly 300,000 years to pass from 12 o'clock to 6 o'clock on the dial. Some 3000 million stars are gathered together within the space of the watch. The whole turns on an axis like a gigantic wheel.

Other Universes. You might well be bewildered with the size of our own great universe, but there are other universes as great as or greater than our own! They are so far out in space that even to the eyes of the most powerful telescopes most of them look like glowing clouds. They are called *nebulae* (singular, *nebula*) from a Latin word which

Yerkes Observatory

This great gaseous nebula, which looks like a cloud, is in the constellation Orion

means "a cloud." Astronomers know, however, that most nebulae are really great collections of definite stars whose light is blurred by the vast distances which separate them from the earth. Another kind of nebula, the gaseous, is shown on page 29.

Back to the Sun. We have traveled a very long way from the sun in trying to answer the question "What are the stars?" Though the sun is but one of many, it is the star in which we are naturally most interested. It is not only the nearest star to the earth but the one that makes possible everything we do. Let us, then, return to the sun and to the little family of the sun which includes the earth on which we live.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Pegasus is one of the largest stars in the sky.

2. Arcturus is a constellation which is located south of the star Vega.

3. The North Star and the constellations near it rise in the east and set in the west like the sun.

4. The names the ancients gave to the constellations long ago are useless now because the stars have since moved into different positions with reference to one another.

5. On a clear night all the larger stars in the heavens may be seen by the naked eye.

6. The stars seem to move from east to west because the earth is turning on its axis from east to west.

7. The axis of the earth is always pointed to the star Vega.

8. Light traveling at about 186,000 miles a minute is used to measure the distances between stars.

9. The sun is a little larger than the average size of stars.

10. All stars are hot, but the reddish ones are hottest.

11. Our universe of stars is shaped like a watch, and the earth is located on the outer edge.

12. A nebula is a great cloud of gas that has not yet gathered together into a star.

Questions for Discussion

1. Sometimes you see the Big Dipper right side up; at other times you see it upside down. How can this be?

2. What stars do you suppose Admiral Peary saw when he was at the north pole? Did he see any of the stars we see much farther south? Would these stars be located at about the same place in the sky? If not, why?

Things to Do

1. Make a star-finder to help you locate and identify the common constellations. See Collin's *Book of Stars* for directions.

2. Many of the stars seem to have peculiar names. Look up some of them, such as Arcturus, Aldebaran, Sirius, and Pollux, and see if you can find why these names were given to them.

3. Study star maps for the different months of the year. What changes do you find from month to month? Give a class lecture on "How to Find the Stars the Year Around."

4. Find out about telescopes and how they are used in astronomy. You may want to construct a simple telescope such as the one described in Collin's *Book of Stars*.

5. Look up the lives of some of the famous astronomers of the past in a good encyclopedia. Write "minute" biographies of Kepler, Copernicus, Newton, and Galileo. Tell what each has done toward the development of knowledge about our universe. Illustrate with pictures or sketches.

CHAPTER TWO

What Is the Solar System?

THE NINE PLANETS

False Notions Die Hard. We learned in the last chapter that most ancient people believed that the earth stands still while the stars circle endlessly around it. This simple but false belief had a very long life. It came down to within a few centuries of the present day. It lasted so long for two reasons: (1) because constellations do actually appear to be moving round the earth, and (2) because it pleased the vanity of men to think of their earth as the center of the universe.

True, a Greek astronomer called Aristarchus, who lived in the third century B.C., taught that the earth was not the center of the universe. He taught that the sun was the center and that the earth revolved around it. But most of the people of his day did not believe him.

Most of the people of many a later day did not believe him either. Not until 1543 A.D. did his idea find another champion. This time it was strengthened by the brilliant mathematical calculations of a Polish astronomer, Copernicus. But even then most people refused to believe. False notions die hard!

Today, however, all thinking people know that Aristarchus and Copernicus were right in their belief that the earth is not the center of the universe. They know that the earth and several other heavenly bodies revolve around the sun. They know this because modern astronomy with the help of the telescope has definitely proved it.

Our Place in the Universe. Modern astronomy has proved not only that the earth is not the center of the universe but that the sun is not the center either. In the last chapter we learned that the sun is only one of some 3000 million stars in the universe of the Milky Way, and that there are many other equally mighty universes in space. The bodies that revolve round the sun are all much smaller than the sun. The earth is but one of these bodies, and far from the largest one at that.

The earth is like a grain of sand in the ocean of space. We two billion human beings who live on that grain of sand are small indeed! We are not, however, so small as our physical size alone would make us seem. It must not be forgotten that though astronomy makes men appear only a little greater than nothing at all, it is men that make astronomy. Their minds are large though their bodies are small. It is only through our minds that we can realize the tremendous size of the universe. The ability to do this gives us a greatness far out of proportion to our physical size.

The Planets. Before men could finally come to a correct understanding of the universe, they had to solve the mystery of certain bright objects in the sky which behaved in a very peculiar manner. While the stars seemed to move across the sky with majestic and unchanging order, these other bright objects seemed to wander around among the stars. The ancient Greeks called them *planets*, a word which means "wanderers." They had no idea of what the planets really were.

With the help of the telescope we have since learned that the planets are moving in nearly circular paths, or *orbits*, round the sun. We have learned that there are at

Copernicus made calculations which proved that the earth is not the center of the universe

least nine planets in the family of the sun, and that the earth is one of them. We have learned that though the planets are very much smaller than the stars, they are very much nearer to us. That is the reason why some planets look larger and brighter than the brightest stars and why the light from all planets is steadier than the light from the stars.

How the Planets Wander. A little observation of the night sky will show you the difference between the twinkling light of the stars and the steady light of the planets. A simple experiment will show you how the planets change their positions with reference to the stars.

Exercise. How to show that a planet changes its position with reference to the stars: Find out from an almanac

which of the planets is the "evening star" at the time during which you are studying this unit. An "evening star" is not a star at all but a planet that is near the western horizon at sunset. Take observations to locate the planet as soon as it is dark. Draw a square on a piece of paper to indicate the section of the sky in which the planet is located. Place a cross in the square to indicate the position of the planet and small circles to indicate the positions of the two brightest stars that appear to be near it. Repeat the observation on several nights. Each night indicate the position of the planet with reference to the stars. Do the stars appear in all the observations to be the same distance apart? Does the planet appear in all observations to be the same distance from the stars or does it appear to change its position with reference to the stars?

If you were to observe the heavens very carefully for many nights, you might be able to see that the planets do not wander in a hit-or-miss fashion through the sky. They follow definite paths, and they travel the same paths over and over again. If you observed the planets long enough, you might discover that each one finally returned to the position in which you first saw it. You might observe, in other words, that *the planets travel in circles.*

It is easy to see that an astronomer can learn more about the planets with the help of a powerful telescope than you can learn without one. Astronomers have already mapped the orbits of the planets as accurately as geographers have mapped the surface of the earth. The drawing on the opposite page is a picture of their map.

Mercury, the Baby Planet. You will notice that Mercury is the smallest planet and also the one nearest the sun. It is about 3100 miles in diameter, which is about 900 miles

The sun and its family of planets

greater than the diameter of the moon. It was named after the messenger of the gods because it travels so rapidly in its orbit round the sun.

The earth requires twenty-four hours to make one complete turn (*rotation*) on its axis and 365¼ days to make one complete trip (*revolution*) round the sun. We speak of the time of one rotation of the earth as a *day*, the time of one revolution as a *year*. Mercury's day is much longer than the earth's day because it turns on its axis (rotates) only once while the earth rotates eighty-eight times.

Mercury's year, however, is much shorter than the earth's year because it completes one journey round the sun (revolves) in the time it takes to rotate once on its axis. Do you see that *its year is therefore the same length as its day*—that is, eighty-eight of the earth's days? Do you see that it must travel very rapidly to make a trip round the sun in so short a time?

People who like to think that life may exist in the universe outside the earth have generally passed by Mercury as a likely home for living creatures. It is too small to have enough gravity to hold the gases which enable living things to breathe, and too near the sun to have the proper temperatures. Astronomers believe that one side of Mercury forever faces the sun, and that the other side forever faces away. The sunny side would therefore be too sizzling hot for living creatures, the dark side too bitter cold.

Venus, the Earth's Twin. The planet Venus is almost as large as the earth (about 7700 miles in diameter). Like the earth, it is clothed with gases. These gases are so thick that astronomers cannot see the surface of the planet and hence cannot tell how fast it is turning on its axis.

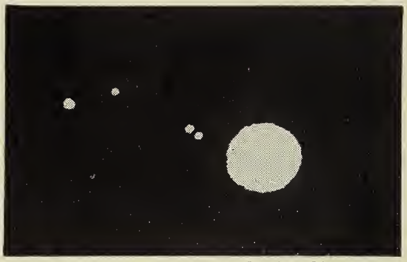
Venus would seem to be a much more likely home than Mercury for plants and animals. Because it is nearer the sun than the earth is, it must have a warmer climate than the earth has, but perhaps no warmer than our tropical jungles, where life is very abundant. It is fascinating to try to imagine whether creatures really live on Venus and what they may be like. Unfortunately we can never know. The thick clouds of gases around that planet guard her secrets well.

Mars, the Ruddy Planet. Let us skip the earth for the time being and consider Mars, the next planet away from the sun. Mars can be told from the other planets because of its color. It is the redhead among the planets.

Though the diameter of Mars (4230 miles) is only a little more than half the diameter of the earth, it may have enough gravity to hold a thin layer of gases which living creatures might breathe. Certain definite changes may be seen to take place on Mars as it circles round the sun. Photographs taken through telescopes during a Martian winter show white caps over the poles which look like ice. These polar caps disappear as summer approaches, as shown in the photographs on the opposite page.

If there is enough moisture in the atmosphere of Mars to form snow and ice at the poles, there may be enough moisture to support life. The appearance of the surface of the planet below the white polar caps changes as the seasons come and go. Some astronomers have suggested that this

change may be due to change in the appearance of vegetation from summer to winter.



Yerkes Observatory

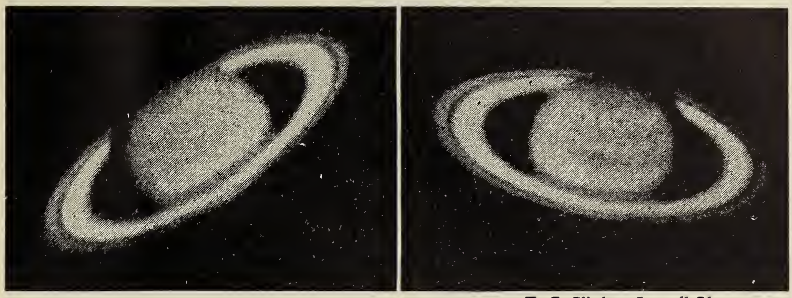
Jupiter and its four largest moons

There are many peculiar markings on Mars which strong telescopes reveal. Certain astronomers once believed that these markings (which look like scratches) might be canals dug through desert regions by intelligent beings, and used as irrigation ditches to carry water from the polar ice caps. Today, however, most astronomers believe that the "Martians," if they exist at all, are plants—and very simple types of plants at that.

Jupiter, the King of Planets. The next five of the sun's family of planets are very much larger (with the exception of Pluto) and very much farther away from the sun than Mercury, Venus, Earth, and Mars. Conditions on the surfaces of these larger and more distant planets are greatly different from conditions on the smaller ones nearer the sun.

Jupiter, shown on page 37, is the largest of all the planets. Its diameter is more than ten times the diameter of Earth. Although it is fifteen times farther away from us than is Venus, Jupiter appears nearly as bright in the sky. It is not only the largest planet but also the most rapidly spinning. It turns on its axis in about ten hours; so its day is less than half as long as ours. Its year, however, is much longer, because Jupiter takes twelve of our years for one trip round the sun.

The strength of the sunlight on Jupiter is only about one thirtieth as great as on the earth, because it is so far from the sun. Astronomers have estimated that the temperature of its surface is about $-150°$ F. This extremely low temperature is far too cold for such living creatures as we know on the earth.

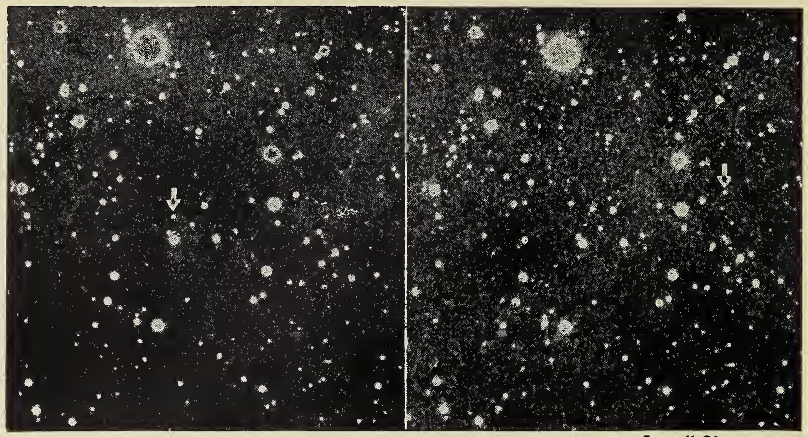


E. C. Slipher, Lowell Observatory

The planet Saturn as it appeared in 1911 and 1916

Exercise. Find out from an almanac when Jupiter will be in a good position for observation. Then obtain a small telescope or a pair of strong field glasses and try to see some of Jupiter's eleven moons. The four largest moons, shown on the opposite page, should be visible if the night is clear.

Saturn, the Planet with the Rings. If you have ever looked through a telescope at Saturn, you have seen one of the most beautiful objects in the sky. You have seen and probably wondered about its rings, as shown in the photograph above. These rings are fine particles of solid matter which revolve round Saturn much as Saturn revolves round the sun. The particles are so close together that they appear from the earth as bands, or rings. Besides its rings Saturn has nine moons, possibly more. This planet is larger than all other planets but Jupiter. The temperature on its surface



Lowell Observatory

Six days passed between the taking of these pictures. The arrows point to Pluto, the planet farthest from the sun. How do these pictures prove that Pluto is a planet rather than a star?

is very much lower than the temperature on the earth and considerably lower even than the temperature on Jupiter.

Uranus, Neptune, and Pluto. The next planet beyond Saturn is Uranus. Its diameter is nearly four times the diameter of the earth, but it is so far away that it is only faintly visible to the naked eye. Sunlight on this distant planet is only one four-hundredth as intense as on the earth. Its cold is more intense than anything we can possibly imagine.

In the far distance beyond Uranus is Neptune, and far beyond Neptune is Pluto. Little is known about the conditions on these bodies because of their great distance from the earth. Notice how faint Pluto, the farthest-distant planet, appears in the photograph above. No wonder that it escaped the notice of astronomers for so long. It was not discovered until 1930.

Tabular View of the Planets. The following table will show you the spacing, size, and speed of the various planets. Do not try to memorize this table. It is given merely as a convenient collection of information which you may want to refer to from time to time as you proceed with this unit.

Planet	Time of Rotation	Time of Revolution	Diameter	Distance from the Sun
Mercury	Probably 88 days	88 days	3,100 miles	36,000,000 miles
Venus	Uncertain	225 days	7,700 miles	67,000,000 miles
Earth	24 hours	365¼ days (1 year)	7,918 miles	93,000,000 miles
Mars	24½ hours	687 days	4,230 miles	141,500,000 miles
Jupiter	10 hours	12 years	86,500 miles	483,000,000 miles
Saturn	10¼ hours	29½ years	75,000 miles	886,000,000 miles
Uranus	Uncertain	84 years	32,000 miles	1,781,000,000 miles
Neptune	Uncertain	164 years	34,800 miles	2,791,600,000 miles
Pluto	Uncertain	249 years	Probably less than the diameter of Earth	3,680,000,000 miles

LITTLE BROTHERS OF THE PLANETS

Comets. Besides the planets there are many smaller bodies circling round the sun. Much the most interesting of these are the comets, which resemble commas with their heads and curving tails. Unknown and unannounced visitors in the sky, gleaming with mysterious brightness, comets were looked upon by the ancients with reverence and wonder. No one knew where they came from or where they went. With time, however, astronomers proved that they travel like planets in orbits round the sun.

Most of you who read this book have probably never seen a brilliant comet. In 1910, when your fathers and mothers were boys and girls, the famous Halley's comet was a very conspicuous object in the night sky. On page 45

you may see a photograph of this comet. This photograph was taken through a telescope, and through a telescope it looked like an immense skyrocket hanging in the heavens, with a tail streaming far out from it. It was easily visible, but not brilliant, to the naked eye, and observers without telescopes could easily watch its passage.

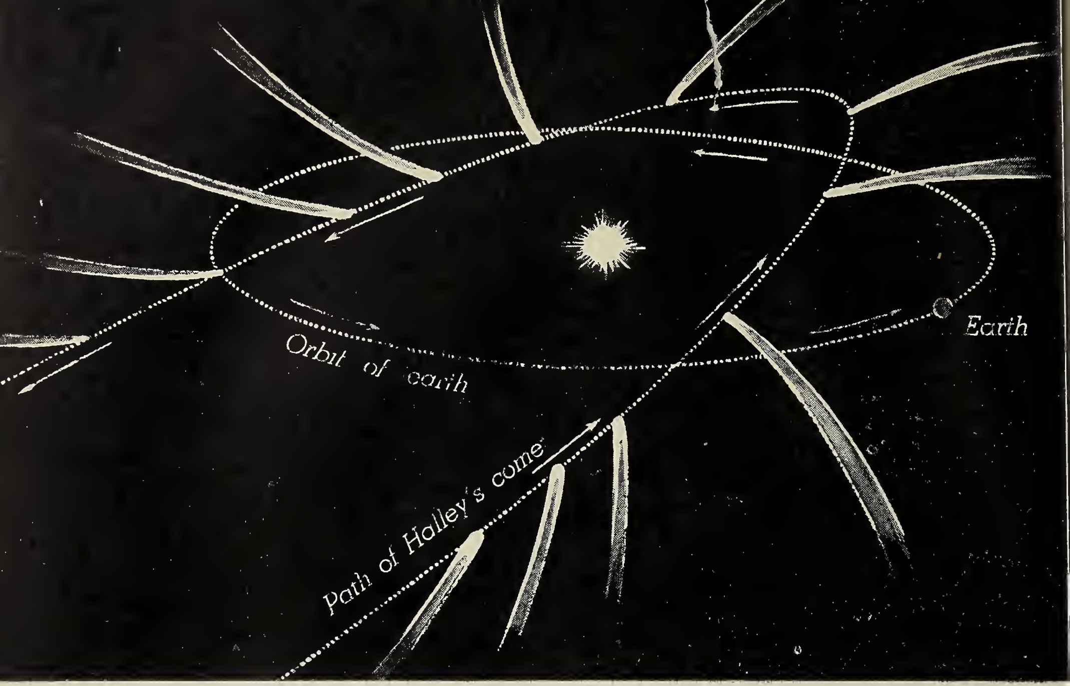
In the course of a few weeks it appeared from the depths of space, moved in a long curve round the sun, and then disappeared beyond the farthest planets. As it approached the sun its tail was *behind* it, where tails belong. As it drew away from the sun, however, its tail was in *front* of it. Its tail, in other words, always pointed away from the sun. The diagram on page 46 shows the way Halley's comet moved across the orbit of the earth. Because it was so far away, the comet seemed to be traveling very slowly. Really, however, it was rushing by at a speed of several thousand miles an hour.

Halley's comet will reach its greatest distance from the earth in 1950. After that it will turn back toward the sun. We know this because astronomers can map the entire route of a comet if they know but a few points along its path. They can tell how long it will take the comet to make a complete journey round the sun. They know that Halley's comet, for example, will appear regularly in the sky above the earth about every seventy-six years.

Superstitious people have always been terrified by the approach of a comet. Even today there is always someone ready to predict the end of the world when a comet appears. Educated people, however, know that there is no relation between the appearance of a comet and happenings on the earth. Comets furnish problems of interest to scientists, but in other respects they exert no influence whatever upon human affairs.

Yerkes Observatory

Halley's comet looked like a giant skyrocket



How Halley's comet is moving round the sun

Planetoids. Many small dark bodies revolving round the sun between the orbits of Mars and Jupiter are known as planetoids. The largest one that has ever been discovered is about five hundred miles in diameter. The smallest ones may be extremely tiny. More than a thousand have definitely been discovered, and there are doubtless many thousands more which are too small to be seen even with the help of the telescope. They are called planetoids because they appear to be much like planets except that they are very much smaller.

Shooting Stars. A "shooting star," or meteor, is not a star at all. It is a small solid body that has moved into the atmosphere of the earth. As it travels through the air it becomes very hot because of *friction* (rubbing) with the air. Small meteors are quickly burned into gas and fine bits of dust which slowly settle to the earth.

At times large meteors pass through the air and fall to the ground. *Meteors that reach the ground are called meteorites.* Many large ones have been found and placed on exhibition in museums. There is one in the American Museum of Natural History in New York City whose weight is about twenty-six and a half tons. It was found by Admiral Peary during one of his trips to Greenland.

The largest meteorite ever found is estimated to weigh between fifty and seventy tons. It was found in Africa, and it still lies where it fell, as shown below. Perhaps the most famous meteorite which ever fell on this country is the one that made Meteor Crater in Arizona, a hole more than four thousand feet in diameter and over five hundred feet deep. A picture of this is shown on page 48. Scientists are pretty well agreed that this crater was caused by the crash of a tremendous meteor. They think that the meteor may have exploded when it struck the earth. Many small

This South African meteorite, the largest ever discovered, is made of iron and nickel

Photo by Samuel G. Gordon, Expedition of the Academy of Natural Sciences of Philadelphia

pieces of meteoric matter have been found in the neighborhood of the crater, but no large ones.

If you watch the sky for an hour on a starlit night, you may see possibly four or five meteors. It is likely that all of these will be small and will last as bright streaks for only a very short time. The chances that you will be able to follow the fall of a meteor until it strikes the ground are very poor. In the whole world this observation is reported only about four or five times each year.

It may seem to you that meteors are rather rare, but that is not true. When you watch the sky on a clear night, you see only the meteors that appear within a circle of not more than fifty miles' diameter. There are many such areas of sky above the surface of the earth, and in every one of them the average number of meteors that may be seen each hour is possibly five or six. At this rate the total number entering the earth's atmosphere in twenty-four hours is

Scientists believe that Meteor Crater in Arizona was made through the explosion of a giant meteor

Atchison, Topeka & Santa Fe Railway Co.

nearly twenty million! If it were not for the fact that the air causes meteors to burn to gas and dust, the earth's surface would be bombarded every day by some twenty million pieces of stone and metal, shooting down at a speed of about twenty-seven miles per second!

The meteorites are the only members of the sun's family, except the earth, that we can observe at close range. Three kinds have been observed. One kind is composed of stony material like the common rocks in the crust of the earth. Another kind is composed of metal. The metal ones are mostly iron and nickel, with small quantities of other elements, such as copper and cobalt. The third kind of meteorite is composed of a mixture of metal and stone. A chemical study of these meteorites shows that they are composed only of chemical elements which are well known on the earth.

When you see one of these meteorites in a museum, you may want to ask where it came from. The only answer that can be made with certainty is that it came from the sky. Many astronomers think that meteorites were at one time parts of comets. These pieces of stone and metal have most certainly traveled through enormous distances. The story of their travels is undoubtedly exciting, but it can never be told.

THE SUN

Sunrise and Sunset. The sun, like many of the more-distant stars, seems to rise in the east and set in the west. We learned in the last chapter that the stars do not really rise and set; that they only seem to do so because of the movement of the earth on its axis. The same is true of the sun, as you may demonstrate in a simple experiment.

Exercise. How to explain the apparent rising and setting of the sun: Run a long needle through an orange and rotate the orange in front of a flashlight, as the children shown in this picture are doing. The rays of the flashlight strike the orange just as the rays of the sun strike the earth. Imagine yourself a tiny observer on the orange. Turn the orange from left to right (west to east) and imagine yourself looking from its surface toward the flashlight. Do you see that the flashlight would seem to be moving from right to left (east to west) and that the orange would not seem to be moving at all?

The above experiment reproduces on a very small scale what happens on earth. The sun seems to be moving from

These boys are demonstrating how the movement of the earth from west to east makes the sun seem to move from east to west

Yerkes Observatory

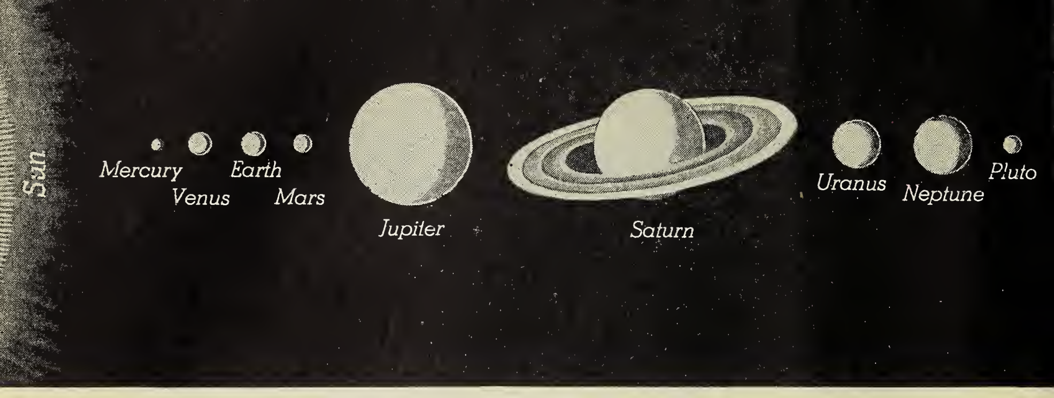
Great tongues of hot gas are shot out far from the surface of the sun and then pulled back by the force of gravity

east to west, but in reality we are moving from west to east with the earth as it turns in that direction on its axis.

The Heat of the Sun. Did you ever visit a steel mill or an iron foundry? If so, you probably watched with excitement the flood of white-hot molten metal as it poured, bubbling and sizzling, from the furnace mouth. You may have wondered how hot this stream of metal really was. If you asked about it, you were probably told that it sometimes reaches a temperature as high as 2700° F.

Even this terrific heat does not begin to compare with the heat of the sun. That glowing ball, which lights and heats the earth, is so hot that it is believed to be made up entirely of gases. At certain times it is possible to see, with a telescope, huge tongues of hot gas shooting out from the sun for hundreds of thousands of miles into space. These are illustrated above. The surface of the sun is probably about 8500° F., and the interior is certainly very much hotter.

The Size of the Sun. Though 93,000,000 miles away and hidden from us half the time, the sun is so large and its light so intense that it controls conditions not only on the earth but on all the other planets. Its diameter (864,000 miles) is more than a hundred times that of the earth. Its volume is therefore more than a million times as great. The relative size of these two bodies and the other planets is



This drawing shows the relative size of the sun and the various planets

shown above. *The amount of material in the sun is more than seven hundred times as great as that of all the planets, planetoids, comets, and meteors combined!*

The Composition of the Sun. With the help of a marvelous instrument called the *spectroscope,* astronomers can learn the chemical composition of heavenly bodies by analyzing the light which streams out from them. The spectroscope has shown that *the sun and all the planets are made of the same materials.* They are all blood relatives, as it were, members of the same family.

No chemical elements are known to exist in the sun that do not also exist on the earth. The chief difference between the earth and the sun is that elements which are solid on the earth are in the form of gases in the sun. Even such metals as iron and aluminum have been detected as gases in the hot atmosphere of the sun.

The Surface of the Sun. The surface of the sun has been studied by means of the telescope, and many photographs have been taken. Dark spots are frequently found on these photographs. These are the *sunspots* which come and go on the surface of the sun. They are very numerous at some times but scarce at other times. A single spot may be

several thousand miles in diameter. Below is an illustration of such a spot, photographed through a telescope.

There is an unexplained relationship between these sunspots and the weather of the earth. Several noted astronomers of the present day are studying sunspots in the hope that they may learn to make long-time weather predictions. Some progress in this study has been made.

Exercise. Look at the sun through a piece of dark smoked glass and describe what you see. Remember that you should never look at the sun on a bright day with your naked eye.

How the Sun Heats the Planets. There are many millions of square miles of hot surface on the sun. Heat moves out from this surface into space in all directions by a process called *radiation.* The intensity with which the rays of the sun strike the various planets varies with the distance of the planets from the sun.

Sunspots come and go on the surface of the sun

Yerkes Observatory

Exercise. How to show that heat is transferred by radiation: Hold a thermometer about two feet from an electric heater. What is the temperature after one minute? after two minutes? after three minutes? Repeat the observations with the thermometer four feet from the heater. The heater radiates heat just as the sun does.

On Mercury, because it is the planet closest to the sun, the heat is most intense. Where its surface is exposed to the sun it is probably almost hot enough to melt tin, that is, 450° F. On Pluto, the farthest planet, the temperature is possibly lower than 320° below zero (Fahrenheit). This is as cold as liquid air. In other words, *if it were to become as cold on Earth as it is on Pluto our air would change to liquid.* Actually, the earth is placed so that it escapes these extremes of heat and cold. About three times as far from the sun as Mercury and about one fortieth as far away as Pluto, its climate is temperate and favorable to living creatures.

The Energy of the Sun. Scientists estimate that the earth receives somewhat less than one billionth of the radiant energy of the sun. So tiny a fraction, however, is enough to keep the earth forever changing. Arriving at the surface of the earth in the form of radiant energy, the heat of the sun lifts water from the oceans by evaporation. This water returns to the surface of the earth, chiefly in the form of rain. Flowing downhill, the rain water turns wheels, which drive electric generators, which produce power, heat, and light for our comfort and safety. Do you see how these things are really all gifts from the sun?

The energy of the sun also enables green plants to take food directly from the water, air, and soil. It thus makes life possible for plants and for animals that live on the

plants. The food we eat—and the things we do with the energy we get from the food we eat—are really all gifts from the sun.

If the sun should suddenly go cold, all these activities would stop. Every creature would drop in its tracks. Fortunately there seems to be no immediate danger of such a tragedy. The sun is not likely to die—at least not for several billions of years.

The Sun is a Typical Star. While it may seem entirely different to us, the sun is yet much like other stars. In size, in brightness, and in the temperature of its surface, it is not far from an average star. To us on the earth the sun seems much brighter than the other stars, but this is only because it is much nearer.

How many of the things which are illustrated here owe their existence to the energy of the sun?

The Solar System. We are now able to answer the question "What is the solar system?" "Solar" simply means "having to do with the sun." The solar system is the sun with its family of planets, planetoids, comets, and meteors, all endlessly circling around it. *The solar system can continue to exist as a family only through the force of gravity.* Through this mysterious force all objects—from a grain of sand to a star—have the power to attract other objects. The larger the object, the greater its power of attraction. So it is that the earth is able to hold you and me on its surface. So it is that the sun can prevent the planets from flying off into outer space. Like a mother hen, the sun keeps her children around her and keeps them warm.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. People gave up the belief that the earth is the center of the universe when Aristarchus proved that the belief was false.

2. We now know that the sun rather than the earth is the center of the universe of the Milky Way.

3. The ancients recognized that although the stars seem to move across the sky the planets seem to stand still.

4. You can always tell the difference between a planet and a star because planets twinkle and stars shine with a steady light.

5. Astronomers have been able to map the orbits of the planets but not very exactly.

6. The earth requires twenty-four hours to revolve on its axis and three hundred and sixty-five and one quarter days to rotate round the sun.

7. Mars is too near the sun to support any but the simplest types of living creatures.

8. Jupiter is the largest and most slowly spinning planet in the solar system.

9. Uranus, Neptune, and Pluto are all about the same size.

10. Comets always travel with their tails behind them.

11. The planetoids are only slightly smaller than the planets.

12. Shooting stars are the most interesting of all stars.

13. The sun is only a little larger than the giant planet, Jupiter.

14. The sun is much brighter than other stars because it is much larger.

Questions for Discussion

1. When bigger and better telescopes are made, what do you think they will show?

2. Do you think that man's gradually increased knowledge of the solar system has made any difference in his ways of living or thinking?

Things to Do

1. Imagine that you had a powerful rocket plane which could travel at a speed of five hundred miles per hour. How long would it take you to reach the different planets from the earth? Prepare a timetable for the Interplanetary Transportation Company, indicating the arrival and departure of the plane at the various planets.

2. Make models or drawings to show the relative sizes of the planets and their orbits. If you represent Mercury as being one inch from the sun, how far away will the earth be on your chart? Jupiter? Pluto?

3. You and a group of your classmates may want to prepare a debate on the question: Resolved that it is highly likely that the earth is the only planet on which life exists.

4. Investigate and report on the discovery of the planet Pluto.

5. Make a special study of some famous comets, such as Halley's, Encke's, Biela's, Morehouse's, or Donati's. You can get information from astronomy textbooks, encyclopedias, and perhaps from histories. Write a booklet giving a description of the comets—their appearance, composition, discovery, relation to the sun and the earth, and any other details which you think are interesting.

6. Obtain information—descriptions and good photographs—of the surface of the sun. Using this information, paint or make crayon drawings to illustrate a booklet on "The Appearance of the Sun."

CHAPTER THREE

What Is the Moon?

A DEAD WORLD

The Moon as a Neighbor. It is impossible to understand a human being without also understanding his relationships with other human beings. Your mother and father, your brothers, sisters, playmates, teachers—to say nothing of the butcher, the baker, and the candlestick-maker—all influence your life. The same is true of stars and planets. They influence the behavior of one another.

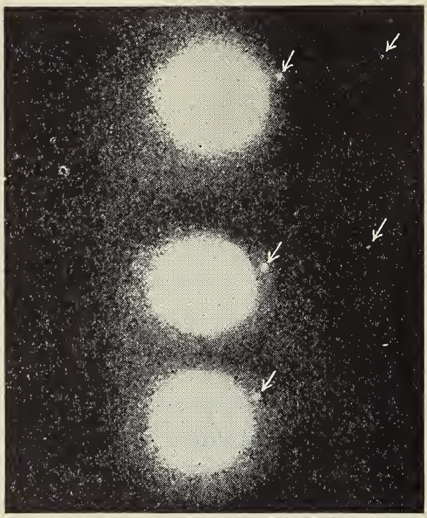
We have seen how the earth and the creatures that live on the earth are under the direct influence of the sun. There is another heavenly body which is second only to the sun in its influence on the earth and her creatures. That body is the moon. Too small to be important in the solar system as a whole, the moon is close enough to the earth to be important to us.

Many common beliefs about the influence of the moon on the earth are merely superstitions. Fortune-tellers often refer to the moon and the planets in practicing their trade of robbing ignorant people. There is not a single reason for believing that the moon or the planets exert any magical influence on our lives.

We sometimes hear people say that the moon affects the weather. There is no good reason for believing this either. The following verse comes much nearer the truth:

The moon and the weather
May change together,
But a change in the moon
Does not change the weather.

Certain important changes in our changing world, however, are governed by the moon. Indeed, to understand the nature of the earth we must also understand the nature of the moon. That is why we shall devote an entire chapter to our nearest neighbor in the sky.



E. C. Slipher, Lowell Observatory

These photographs of Mars, taken at three different times, show the moons of that planet. One is so small that it cannot be seen in the bottom photograph

The Satellites. *Any smaller heavenly body that revolves round a larger one is called a satellite.* The word "satellite" means "attendant," and is used because of the fancied resemblance of the satellites to the attendants who follow princes and other powerful persons. In this same sense the earth and the other planets are satellites of the sun. Ordinarily, however, the word is applied only to the moons that revolve round the planets.

We have already seen that the earth is not the only planet that can boast a satellite. We have seen that Jupiter has eleven moons. Three of these are larger than our moon and two are fully as large as the planet Mercury. Saturn, too, has nine moons and possibly more. Uranus has four moons, and Neptune at least one. Even the little planet Mars has two tiny moons to guard it, as shown above.

The Nearness of Our Moon. Though our moon is only 2162 miles in diameter, it is much our nearest neighbor in the sky. For that reason it seems a great deal larger than it really is. Actually it is 238,800 miles away, but this distance is a mere nothing as sky distances go. It is only about ten times the circumference of the earth.

There are automobiles and airplanes in existence which have been driven more miles than the distance from the earth to the moon. If you could travel through space with the speed of a fast airplane, you could reach the moon in *fifty days*. At the same speed you would need more than *fifty years* to reach the sun.

A Desolate World. The moon is a solid globe, without air and without life. It would also be a dark globe were it not for the light of the sun. When you look at the bright face of the full moon, you see a body that is glowing with borrowed light. The rays of the sun illuminate the moon just as the rays of your flashlight illuminate the eyes of a black cat on a dark night. This illumination is then reflected toward you so that you see the moon as a bright object.

If you could look at the surface of the moon through a telescope, you would see a vast barren desert of mountains and plains. The photograph on pages 62–63 is a typical scene on the surface of the moon. Notice the strange circular pits that scar the moon's face. They are called *craters* because it was once thought that these holes were the outlets for extinct volcanoes. Today astronomers rather generally believe that the "craters" were produced by the crash of giant meteors. Without air to burn up these visitors from the sky, the moon has no way of protecting itself from their fury.

There are also several mountain ranges on the moon, like the one shown on page 64. These mountains are unlike any mountains on earth. Without wind and water to wear them down, they stand with a steepness and ruggedness unknown among the mountains of our planet. Without air and water, no growing thing can exist to brighten the bleakness of these peaks and plains. The moon is therefore more desolate than the most barren deserts of the earth.

Does the Moon Turn on Its Axis? Suppose you were out in space looking at the earth with long-distance eyes. If you watched it for a period of twenty-four hours, you would see its entire surface as the earth rotated on its axis. You would see the patterns of all the

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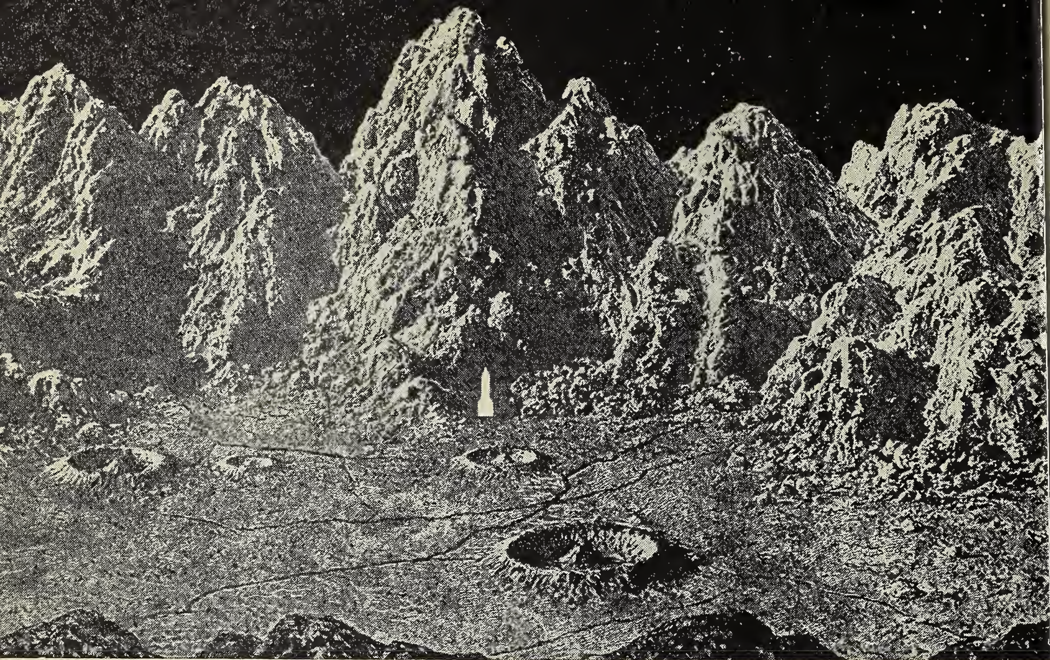
Lick Observatory and A. M. N. H.

The face of the moon is scarred with circular pits



The great mountains of the moon are steeper and bleaker than any mountains on the earth.[1] The little white symbol represents the relative height of the Empire State Building of New York

continents of the earth during this twenty-four-hour period of rotation, together with all the oceans, plains, and other physical features.

How is it, then, that you never see more than the one pattern on the face of the moon—the one that some people see as a "man in the moon"? This pattern does not change. If the rotation of the moon on its axis were similar to that of the earth, you would see all the surface of the moon as it turned. As it is, you see only one side. Does this mean that the moon does not rotate?

The answer is No. The moon does actually rotate on an axis. *The reason you do not see more than one side of the moon at any time is that the period of rotation is the same as the period of revolution.* The moon, therefore,

[1]From Nasmyth and Carpenter, *The Moon*, published by John Murray.

always keeps the same side toward the earth, turning just fast enough to keep this one side of its surface exposed to our view. A simple experiment will show you how this takes place.

Exercise. How to illustrate the manner in which the moon turns on its axis: Stand facing a chair and then walk "sidewise" around the chair, keeping your face all the time toward the chair. In this manner you "revolve" round the chair as the moon revolves round the earth. During one revolution you also "rotate" once. An observer in the chair sees only one side of you as you "revolve" and "rotate."

Do you remember that Mercury moves about the sun in this same way? Mercury revolves once as it rotates; so it has always the same portion of its surface exposed to the sun.

THE PHASES OF THE MOON

The Moon's Changing Appearance. The moon takes about four weeks to revolve round the earth. As it travels in its orbit, the part facing the sun is bright and the part turned away from the sun is dark.

Yerkes and Lowell Observatories

The lighted side of the moon presents different shapes, or phases, to our eyes

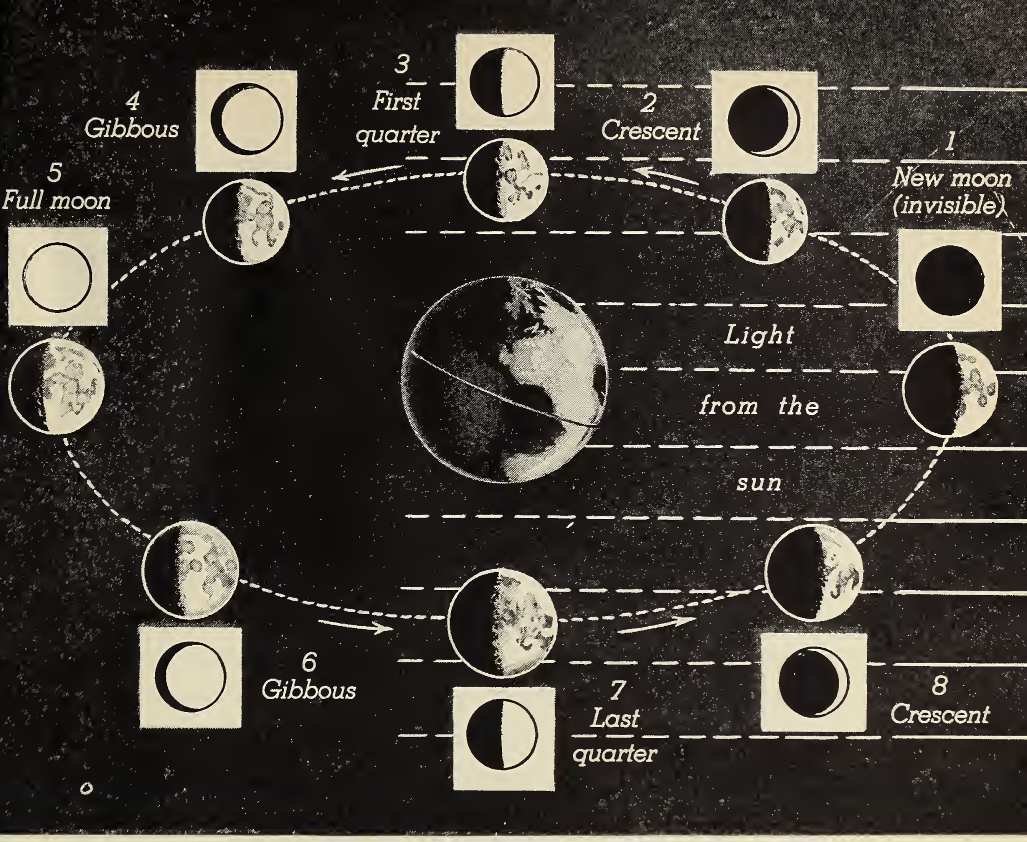
As it circles around us, the moon presents different views of its lighted side, as shown in the photographs on page 65. We call these different shapes which the lighted side of the moon presents to our eyes the *phases* of the moon.

All of us have seen and talked about the phases of the moon. "What a wonderful full moon there is tonight!" and "Look at the thin crescent of the new moon" are remarks that all of us have made. Let us now see if we can discover why the moon presents these different appearances.

You may find the following paragraphs a little difficult, but do not be discouraged. You *should* find them a little difficult because they call for the use of the imagination, which is apt to be somewhat lazy. After you have gone over the following explanation alone, go over it again with your classmates and teacher. Be sure you understand each step in the explanation before you go on to the next.

The Explanation. Study the diagram on page 67 carefully as you read the following explanation. Notice that the orbit of the moon around the earth is indicated by a dotted line. Notice that the moon with its light and dark sides is shown at eight positions in its orbit. Notice also that outside each position of the moon in its orbit is a diagram which shows how the moon appears to us when it is in that position.

It is easy to understand that the moon is invisible to us when it is in a position between the earth and the sun. The side of the moon that faces the earth is *wholly* unlighted in this position. This condition is represented in position 1 of the diagram, and is known as the *new-moon* phase. The new moon, as you can see in the diagram, is really no moon at all so far as its visibility from the earth is concerned.



This diagram shows how the phases of the moon are produced

As the moon moves forward in its orbit to position 2, part of the side of the moon which is turned to the earth comes into the light of the sun. We see this part as a crescent, and people sometimes speak of it as the *crescent moon*. About seven days after the time of the new moon, the moon has moved to position 3, where half its lighted surface is visible to us in the shape of a half circle. We speak of this phase as the *first quarter* because it represents one quarter of the journey of the moon around the earth.

As the moon continues in its travels, it gets into positions where more and more of its lighted side is visible to us. At position 4 the moon looks like a poorly drawn circle and is said to be in the *gibbous* ("hunched") phase. About

fourteen days after new moon the *full-moon* phase is reached. At this stage (position 5) the earth is between the sun and the moon so that all the illuminated side of the moon is visible to us.

When the moon has reached position 6 it has been shaved down to the gibbous form. At position 7 it has returned to the appearance it had in position 3, wherein half the lighted side is visible to us. We say that the moon in position 7 is in the *third, or last, quarter* because it is three-quarters through its journey round the earth. It then passes through the crescent form again, as shown at position 8 (the *old crescent*, as it is sometimes called). Finally, after about twenty-eight days, it enters the new-moon phase and is ready to begin its journey all over again.

Do you see how the moon can appear in so many shapes, or phases, without really ever changing its shape at all? Do you see that all these phases are visible from all points on the earth because the earth turns on its axis about twenty-eight times while the moon circles round it but once?

WHAT ECLIPSES ARE

Preparing for an Eclipse of the Sun. The moon does more than make night interesting and beautiful for us dwellers on the earth. From time to time it causes one of the most exciting spectacles a human eye can witness. That spectacle is an eclipse of the sun.

For weeks and even months before the event we read in the papers about its coming. We are told that at a certain time on a certain day the light of the sun will be blotted out. Those of us who have never seen such a thing wonder if it can be true.

© W. J. Bresnan

This series of photographs tells the story of a total eclipse of the sun

Many people get busy smoking pieces of glass over candles so that they may watch the sun during its eclipse without harming their eyes. Many other people buy colored spectacles. Amateur photographers discuss the possibility of taking pictures of the eclipse with an inexpensive camera. Colleges and other institutions of learning send scientists long distances to places where the eclipse may be best observed. Cameras attached to telescopes are set up long before the great day comes.

Watching an Eclipse of the Sun. Finally the eclipse arrives. The eager observer is thrilled to see through his smoked glass that a small bite seems to have been taken out of the rim of the sun. While he watches he sees more and more of the sun being cut away until it narrows to a small crescent. The series of pictures above shows the stages of a typical eclipse.

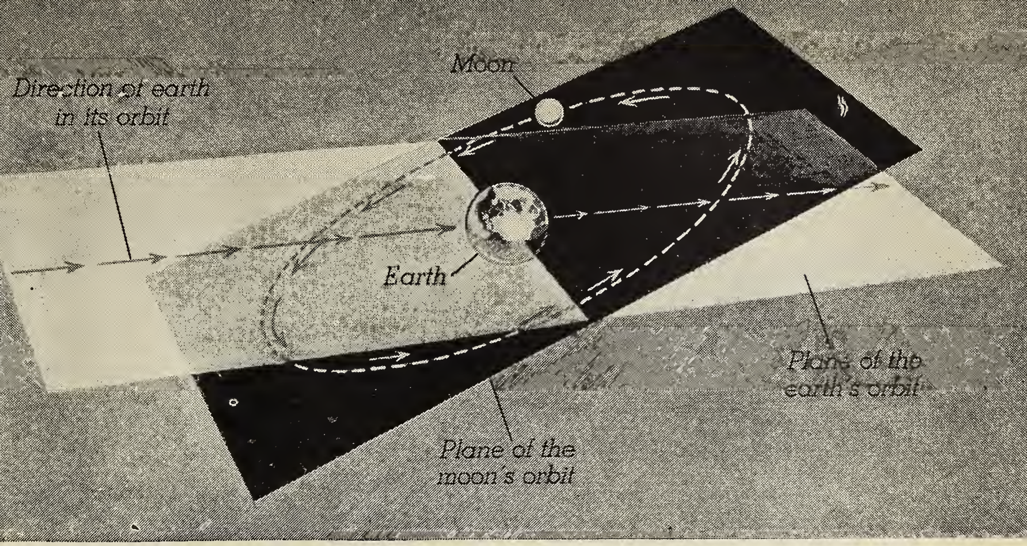
While the sun is being blotted out the air grows cooler. Things take on a strange appearance in a strange, unearthly light. The sky grows rapidly dimmer until the stars come out. Mercury, always near the sun, gleams brightly. When the disk of the sun is entirely blotted out, the most exciting part of the eclipse takes place. A brilliant rim of light shines out from the edges of the blackened disk. This light is called the *corona* ("crown") of the sun and is never

visible except when the sun is completely hidden in an eclipse. All too soon the wonder passes. After an interval ranging from less than one minute up to, on rare occasions, five or six minutes the world takes on its ordinary appearance. The observer rubs his eyes as though awakening from a dream.

History tells how primitive men and women were terrified by eclipses. If you have ever seen a total eclipse of the sun, you will understand their fright. The dimming light and the appearance of the stars in the middle of the

During an eclipse of the sun weird light from the corona plays on Profile Mountain, New Hampshire

© Yerex Studio



The orbits of the earth and the moon are on different planes

day, the strange look of the landscape, the complete blotting out of the sun might well suggest the end of the world to ignorant people. Today, thanks to the observations and conclusions of scientists, no one need fear an eclipse of the sun. We know that the passing of an eclipse is no more dangerous than the passing of a cloud.

Explaining an Eclipse of the Sun. Now that we have described the appearance of an eclipse of the sun, let us see if we can explain it. Here again we must use our imagination to understand what happens.

An eclipse, or "blotting out," of the sun occurs when the moon, in passing between the earth and the sun, cuts off the light of the sun. You may ask, "Why, then, do we not have an eclipse of the sun with every new moon? According to the diagram on page 67 the moon is directly between the earth and the sun once every revolution."

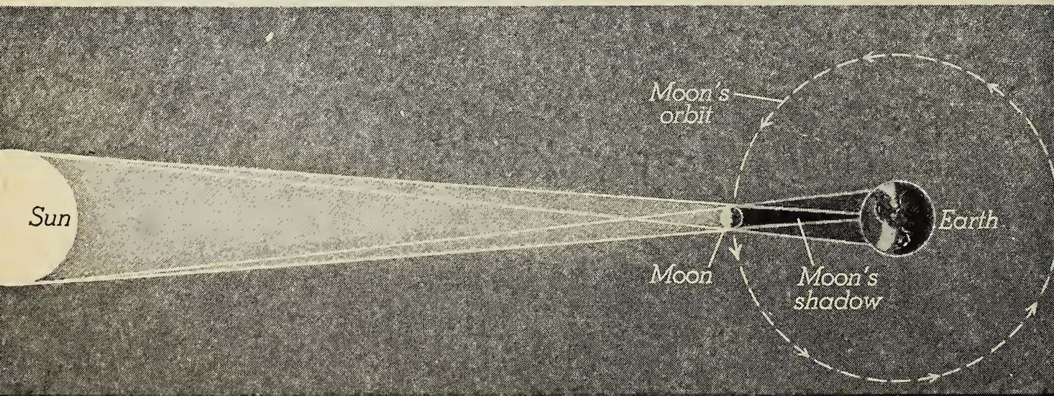
The answer to this question is easy. *The orbits of the earth and the moon are not in the same plane, like the grooves on a phonograph record.* If they were in the same

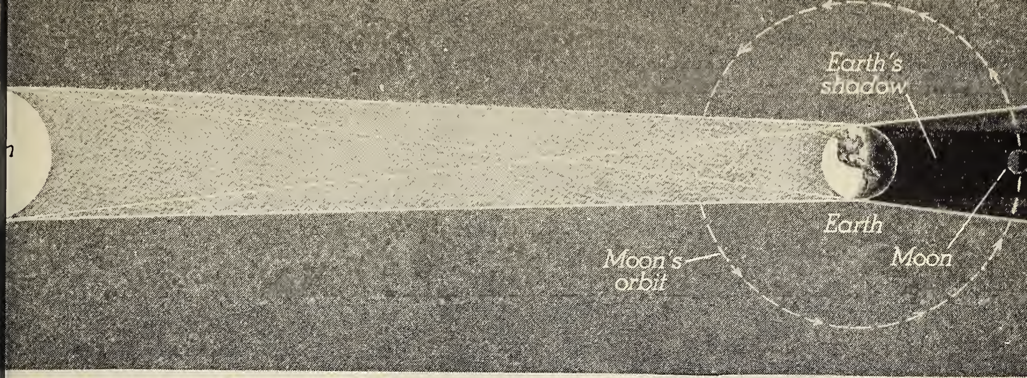
plane, there would be an eclipse of the sun every time the moon got between the sun and the earth. Actually, the plane of the moon's orbit is tilted away from the plane of the earth's orbit just enough so that the shadow of the moon will ordinarily miss the earth. Because of this the moon can ordinarily pass between the sun and the earth about every twenty-eight days without causing an eclipse of the sun. The drawing on page 71 will show you why this is possible.

At times, however, the earth, moon, and sun come together in a straight line, with the moon directly between the earth and the sun. A cone-shaped shadow of the moon will then fall on the earth, as shown in the diagram below. Because the moon is small its shadow will cover only a narrow band of the earth's surface. Only in this band will the sun be totally eclipsed.

Eclipses of the Moon. Compare the diagram on this page with the diagram on the next page. In the second the shadow of the earth is falling on the moon and producing an eclipse of the moon. Do you see that an eclipse of the sun and an eclipse of the moon are produced in the same way, except that in the one the moon casts the shadow while in the other the earth casts the shadow?

An eclipse of the sun takes place when the moon passes directly between the earth and the sun





An eclipse of the moon takes place when the earth passes directly between the sun and the moon

THE MOON AND THE TIDES

High Tide and Low Tide. People who live near the ocean know something about the daily rising and falling of the tides. At no one place on the seashore, however, can you learn all about the tides. Indeed, you cannot learn all about the tides until you turn from the sea to the moon, because the moon is the chief cause of the tides.

Twice each day the surface water of the ocean rises in its bed, and twice each day goes back to bed again. When the flood of water over the shores is at its peak, we say that the tide is *high*. When it returns to its original position, we say that the tide is *low*.

The amount of flooding brought about by the tides is not the same on all shores. Along the coast of Florida the difference between high and low tide is generally very slight,—only about one foot. Remember, however, that this foot is measured in height (vertically). A one-foot rise of the ocean may flood many square miles of low-lying country.

You can imagine from this the mighty changes which are brought about, even on fairly steep shores, by tides of many feet. At the head of the Bay of Fundy in eastern

U. S. War Department

Boats climb up the sides of wharves in the Bay of Fundy as the fifty-foot tide comes in

Canada the tide is the highest in the world. You might stand on the shore of this bay at low tide on a spot which six hours later will be under fifty feet of water!

Tides in the Bay of Fundy. What does a fifty-foot tide mean to the people who must adjust their lives to it? The photographs on this page will help you understand what it means. It is an interesting experience to stand on such a wharf as is shown in these pictures and watch the boats climb higher and higher as the water rises beneath them.

Where the tide passes through narrow inlets at the head of the Bay of Fundy, it makes a never-to-be-forgotten sight. The photograph on the opposite page shows the tide coming into such an inlet. Notice that it is moving in from the sea in a mighty wave. This wave is called a *tidal bore.*

The bore passes an observer on shore in about four minutes. During that time the water may rise as much as six feet. Naturally, boat and ferry schedules in this region must be planned with reference to the tides.

What Causes the Tides. How do these changes in the level of the oceans take place? To answer this question we must consider again the mysterious force of gravity. We have seen how this force of attraction between the sun and earth and the other planets holds these bodies in their orbits. In the same way the force of gravity between the earth and the moon holds the moon in its orbit.

The pull between the earth and the moon, however, is not all in the direction of the earth. Though smaller than the earth, *the moon has some pulling power too.* This moon-pull actually stretches the rocks of the earth a little bit. It stretches the weaker waters of the earth a great deal. The "stretching" of the water in the oceans produces the tides.

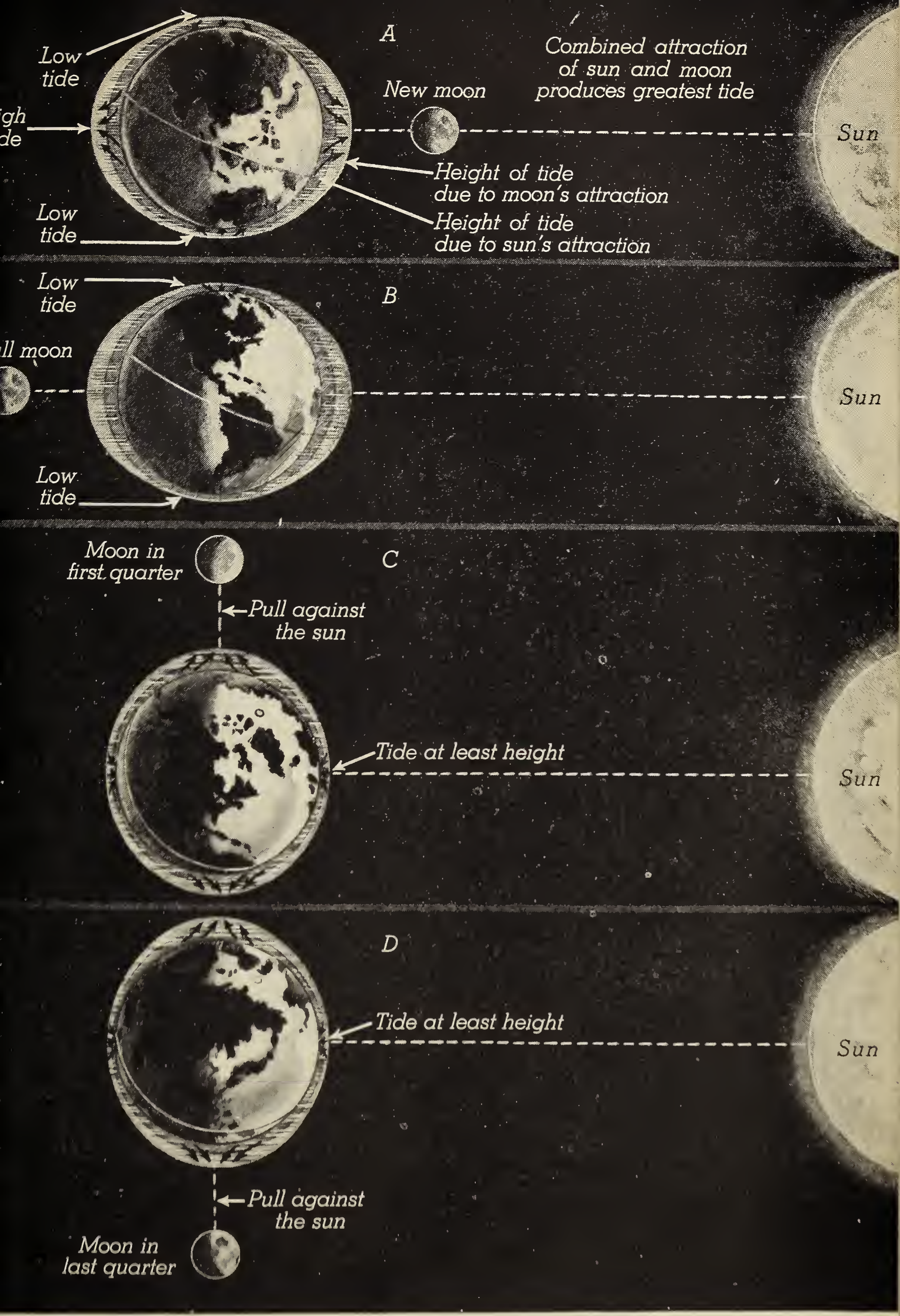
The tide moves into the Bay of Fundy as a mighty wave

The water closest to the moon is naturally attracted most. It rises in a slight bulge on the side of the earth which faces the moon. As the earth turns on its axis the crest of this bulge moves round so that it is always facing the moon. Another bulge of water is produced on the side of the earth which is opposite the moon. It is impossible to explain in simple terms how this second bulge is produced. It is enough for you to know that *there are always two tidal bulges in the oceans*, one on the side of the earth which is nearest to the moon and one on the opposite side.

The force of gravity between the sun and the earth also takes part in producing the tides. Though much larger than the moon, the sun is much farther away from the earth. The result of its pull on the oceans (*solar tide*) is therefore much less than the result of the pull of the moon (*lunar tide*).

The illustration on the opposite page shows how the sun and the moon produce the tides. At new moon and full moon the sun, moon, and earth are nearly in a straight line, and sun and moon are pulling together (see *A* and *B*). *At such times the tides are greatest.* When the moon is in its first quarter, as shown in *C* (and also in its last quarter, as shown at *D*), the attraction between earth and moon is not in the same direction as the attraction between earth and sun. *At such times the tides are least.*

How Tides Help Men. Have you ever been at the seashore when the tide was low? If so, you may have seen the clam-digger grubbing in the mud with a clam hoe. Only when the tide is low can he reach the clams. Many other kinds of shellfish are most easily reached at low tide; so the tide is a help to many of the people who get their living from the sea.



How the sun and the moon produce the tides

Tides are also very helpful to sailors. The great ships which go back and forth across the oceans must have deep places to dock near the shore. The tides act as brooms which sweep the sand and mud from the world's harbors and keep them deep. Many rivers which empty into the oceans drop sand and mud at their mouths. If it were not for high tide, which raises the water above these barriers, seagoing ships could never get into these rivers. The great Liverpool harbor and other harbors in rivers are made possible by the tides.

We have now learned something about the stars, the planets, the sun, and the moon. We have seen how they all play their parts in the moving picture of the sky. We have seen how the earth fits into this moving picture.

We have not, however, seen many of the changes which are forever taking place on the earth itself. These changes are caused by energy from the sun and are so numerous and important that we shall need all the remaining units of this book to help us find out what they are.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. The moon is the chief cause of changes in weather.

2. In having a moon the earth is different from all the other planets.

3. Next to the sun, the moon is our nearest neighbor in the sky.

4. The surface of the moon is spotted with holes, which most astronomers believe to be the craters of extinct volcanoes.

5. The fact that you always see the same side of the moon proves that it does not turn on its axis as it revolves round the earth.

6. All phases of the moon are beautiful, but the new-moon phase is the most beautiful of all.

7. When the moon is gibbous, it appears as a half circle to our eyes.

8. It takes the moon two weeks to make one trip round the earth.

9. An eclipse of the moon occurs when the moon gets between the earth and the sun and cuts off the rays of the sun.

10. The earth and the moon are traveling in circles which lie in the same plane, like the grooves on a phonograph record.

11. An eclipse of the sun occurs at rare intervals when the earth's shadow falls on the sun.

12. Tides are produced chiefly by the pull between the sun and the oceans, helped a little by the pull between the moon and the oceans.

Questions for Discussion

1. Do you believe that there are "craters" on the side of the moon which we cannot see? Why?

2. How do you suppose high and low tide at a given place along the ocean can be accurately predicted months in advance?

Things to Do

1. Look up the satellites of the other planets and report on them to your class. Compare them in size, appearance, and speed of revolution with our moon.

2. Make demonstrations to illustrate the results of the movements of the moon. Lay a flashlight on a pile of books in a very dark room to represent the sun. Use an orange to represent the earth and a small white rubber ball to represent the moon.

a. Make the "moon" revolve round the "earth" in the light of the "sun" so that an observer on the "earth" will see the various phases of the "moon." Use the diagram on page 67 to help you set up this demonstration.

b. Arrange the "earth" and the "moon" in such a way that the shadow of the "moon" falls on the "earth" and produces an "eclipse of the sun."

c. Produce an "eclipse of the moon" by making the shadow of the "earth" fall on the "moon."

3. Read the story of the eclipse of the sun of August 31, 1932, in the *National Geographic Magazine* for September, 1932.

4. In Mark Twain's *A Connecticut Yankee in King Arthur's Court* you will find a humorous story of how the knowledge of a coming eclipse saved the hero from a lot of trouble. Read it. You may know of some similar stories. Tell the class about them. Perhaps you may want to write one of your own.

5. If you live near the ocean, make a study of tide tables for the next month. Do you find that the time of low tide and high tide varies? Is there any relationship between these differences and changes in the moon?

UNIT TWO

THE CHANGING AIR

An astronomer on Mars with a good telescope could see that the earth is all bundled up in a blanket of gases.

He could see that these gases turn with the earth on its axis and cling to the earth as it rushes around the sun.

If he wanted to learn about the earth, he would probably first want to learn about the gases that surround it.

As a dweller on Earth you have a much better opportunity than the imaginary astronomer on Mars to study these gases which we call the air.

You live at the bottom of the air somewhat like a fish at the bottom of the sea.

You breathe air as a fish breathes water.

You feel air when it is moving in winds just as a fish feels water when it is moving in waves.

You know that the air is always doing something, always changing.

No changes in this changing world touch your life more often than the air changes which are known as weather.

But have you ever wondered what weather really is?

Do you know how scientists can tell today the kind of weather your town will have tomorrow?

Do you know what climate is and how the climate of the United States compares with that of other lands?

Unit Two of this book will try to help you find answers to these questions.

CHAPTER FOUR

What Is the Drama of Weather?

HOW TO STUDY THE WEATHER

Whether it's cold, or whether it's hot,
We must have weather, whether or not!

This wise old jingle reminds us that the weather is always with us and that we might as well accept it without fretting. Mark Twain once said that everybody talks about the weather but nobody ever does anything about it. There is much truth in this remark. We can protect ourselves against the weather with proper clothing and shelter. We can know a little in advance what kind of weather to expect, and we can make our plans accordingly. In other words, *we can change ourselves to suit the weather—but we cannot change the weather.*

Weather, however, is constantly changing of its own accord. Change, in fact, is its most striking feature. "If you don't like New England weather," to quote Mark Twain again, "wait a minute." What is true of the weather in New England is true of the weather in most other parts of the globe. It is forever changing, not generally from minute to minute or hour to hour, but from day to day and week to week.

While it is clear in Chicago it may be cloudy or rainy in Boston. It may be snowing in Denver while it is sleeting in Dubuque. It may be misty in a valley and at the same time sunny on the hills which surround it. Each of these conditions today may change in each of these places tomorrow or even before tomorrow.

George French from Nesmith

The snowstorm is a familiar type of weather in the North

Being One's Own Weather Bureau. Anyone who has ever visited a station of the Weather Bureau knows that it is filled with complicated and costly instruments. Have you ever realized that you can gather many facts about the weather without any instruments at all? Our bodies are not thermometers or wind gauges or any of the other instruments which the weatherman uses. Nevertheless they can tell us much about the weather. They can also tell us much about what the weather does to us.

Being One's Own Thermometer. Does it seem hot, warm, cool, or cold outdoors now? Is there any *regular* difference

in your feeling of warmth and cold between morning, noon, afternoon, and evening? Has there been any *sudden* change in your feeling of temperature during the day? What is the difference between your feelings today and yesterday? In what way are you generally affected by very hot weather? by very cold weather? Are other people affected in the same way? Does there seem to be any regular system of temperature changes throughout the day? throughout the week? throughout the month?

Exercise. Keep a daily record for a week of temperature changes as they affect you. The following is a sample of the kinds of observations you should record and of the way you may record them:

Thursday, October 3, 1940		
Hour	**Temperature**	**Remarks**
8 A.M.	Very chilly	Colder than yesterday morning
Noon	Much warmer	Sun quite warm but cool in shade
3 P.M.	Somewhat cooler	Began getting cooler at 2 P.M.
8 P.M.	Colder	Steadily growing colder. Expect frost tonight

Being One's Own Wind Gauge. What is the direction of the wind today? Is it moderate, brisk, or high? Has its velocity (speed) changed any during the day? since yesterday? Is there any relation between the direction of the wind and its velocity? Does the wind change its direction suddenly or gradually? Have you observed any calms? Have you observed any regular changes in the direction or velocity of the wind?

Keystone

The hurricane is a dreadful type of weather in the tropics

Exercise. Keep a daily record for a week of wind conditions as they affect you. Make charts for each day which are similar to your temperature charts but which have columns for wind direction and wind velocity. Make your observations on wind at the time you make your observations on temperature. See if you can discover any relationships between temperature conditions and wind conditions. Use the following scale to describe the velocity of the wind:

CALM: leaves of trees dead still; smoke rising in vertical columns
LIGHT: leaves of trees barely moving; smoke drifting
BRISK: branches moving; dust swirling
HIGH: whole trees swaying
GALE: branches broken; bricks loosened in chimneys
HURRICANE OR TORNADO: buildings blown down

Being One's Own Rain Gauge. Is the sky clear, partly cloudy, or cloudy today? Is it more or less cloudy than it was yesterday? Does it look like rain? How exactly does it look when it looks like rain? Does most of the rain come in showers or in storms which last a day or two? Does your locality have about the same amount of rain or snow each week? each month? Does the amount vary a great deal from week to week and from month to month? How do you feel when it rains?

Exercise. Keep a daily record for a week of rainfall and related conditions. Make these observations at the time when you make your observations on temperature and wind. See if you can discover any relationships between temperature, wind, and rain. The following is a sample of the kinds of observation you should record:

Monday, October 7, 1940			
Hour	**Sky**	**Rain (or Snow, Frost, Etc.)**	**Remarks**
8 A.M.	Overcast	A gentle drizzle	Looks like an all-day rain
Noon	Partly cloudy	Rain stopped	Weather changing; may swing almost any way
3 P.M.	Clear	No rain	Only a few small drifting clouds
8 P.M.	Clear	No rain	Stars bright, no clouds at all

What Weather Is. While we are keeping records of the differences and changes in weather, we shall go on in this chapter and try to learn what causes them. We might define weather as *the condition of the lower air in a given region at a given time.*

This definition tells us what weather is, but it does not tell us why it is constantly changing from place to place and from time to time. To understand this we must take the air apart as we would take a clock apart. We must learn what "makes it go." This may seem a difficult thing to do because the air is so thin and light and transparent and at the same time so vast. But the scientists have shown us how it can be done. After you have done it you will probably agree that it was not nearly so difficult as you expected it to be.

AIR, THE MOTHER OF WEATHER

Exploring the Ocean of Air. Have you ever heard about Auguste Piccard or any of the other scientists who have explored the mysterious regions of the upper air? Now that both poles have been reached again and again and many of the higher mountains climbed, the upper air is a popular region for exploration. No explorer, however, has yet reached the far-distant surface of the sea of air. No explorer may ever reach it.

Men, being what they are, however, will go on trying to reach it. They have already won to ever higher and higher altitudes, and they will doubtless go still higher in the future. Men in balloons have now risen nearly twelve miles above the earth. Balloons with recording instruments, but without men, have risen to more than twenty miles. What can these men and instruments tell us about the air?

The Air Is Layered Like an Onion. All observations agree that the air is divided into regions which lie one on top of another like the curved layers of an onion. Very little is known of such uppermost layers of air as may exist. The bottom layer, however, has been fairly well explored. A

second layer has been partly explored, although no balloon has yet been able to reach the top of it.

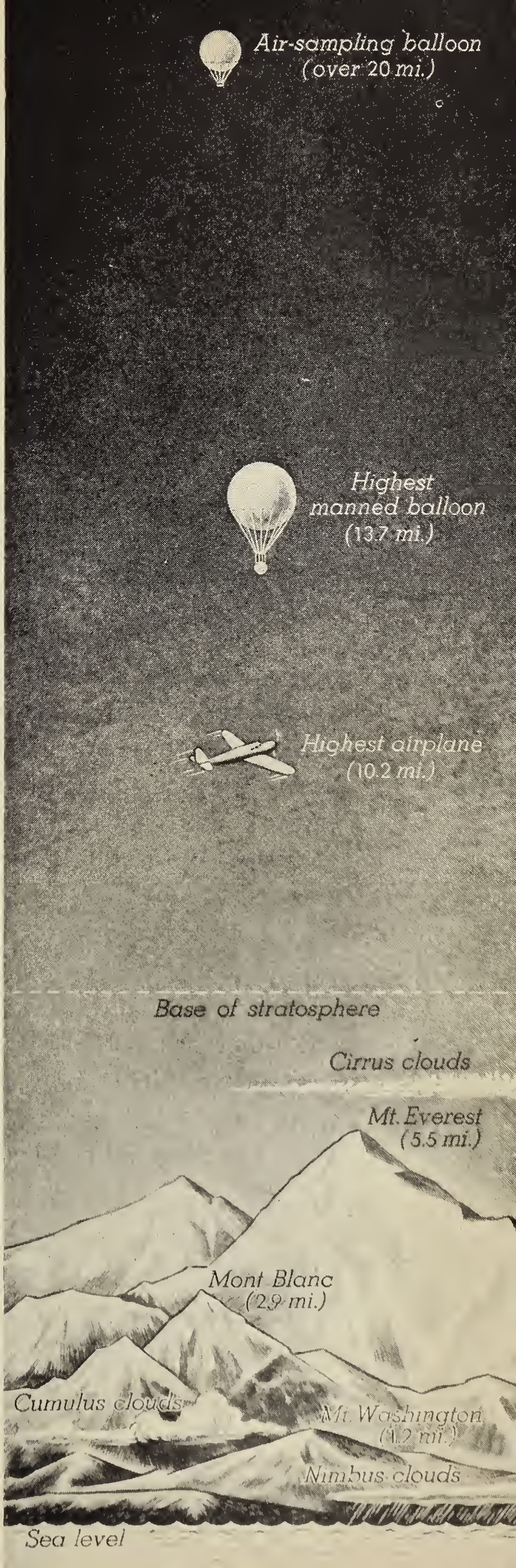
It was once generally believed that the higher we should rise in the air, the colder it would become. People thought that finally, perhaps one hundred miles above the surface of the earth, they would find the terrible cold of outer space ($-459°$ F.). After balloons with thermometers had begun to explore the air, however, people experienced an astonishing surprise. The thermometers showed that *though temperature begins to fall steadily with increasing altitude, it ceases at a fairly definite level in the air to fall any farther.* Above this level up to the highest point yet reached by man the temperature does not decrease with height.

The Upper Air. The zone in which temperature does not fall with height is called the upper air or *stratosphere.* "Strato" means "layer," and it refers to the onion-like structure of the air which we have just described. The stratosphere begins in our latitudes about seven miles above the ground. Over the poles it begins about five miles, and over the equator about ten miles, above the ground. The lower boundary of the stratosphere varies also with the seasons. But no matter where the place or what the season, the break between the lower and the upper air is fairly definite and abrupt. It is everywhere and always marked by a fairly definite and abrupt stop in the fall of temperature with height.

The largest balloon ever built is about to set off for the stratosphere

What do you suppose accounts for the variations in the level at which the stratosphere begins? Why do temperatures fall steadily until the stratosphere is reached and then suddenly stop falling? You probably cannot answer these questions now, but keep them in mind, because we shall return to them later.

If you were to leave Chicago on a hot day in mid-July on a balloon trip to the upper air, you would find the temperature falling, very irregularly at first but more steadily higher up. At 3000 feet above the sea it would have fallen perhaps from 90° to 60°. At two miles it would be down around 32°, the freezing point of water. At three miles it would be close to zero. At five and a half miles (about the elevation of Everest, highest mountain peak on earth) it would be down to 25° *below* zero. At seven miles it would be down to 67° below zero. And in mid-July!



A Weatherless World. Above seven miles, however, the temperature would drop no farther. It might even rise a little at first. No matter how much higher you should climb, the temperature would stay around 67° below zero. Why, you wonder, should it do so?

While puzzling over the solution of this mystery, you notice that the clouds through which you passed to reach the stratosphere are gone. The winds have died down. You are in a region of calm—cold, dry, and dead. It suddenly dawns on you that you are in *a region without any weather.* Without changes in temperature, without the ever-shifting clouds and winds, there can be no weather such as you have experienced at the surface of the earth.

The Lower Air. All the air beneath the stratosphere is called the lower air or *troposphere.* "Tropo" means "something that turns or changes." It refers to the ceaseless changes which make the lower air so different from the upper. The troposphere is the ever-changing region of weather. We shall study it throughout the remainder of this unit.

We suspect that the strange difference in the behavior of the thermometer in the lower and the upper air may give us a clue as to why the one region has weather and the other has not. If we only knew exactly how air is heated, we might know what brings weather to the one region and what keeps it away from the other. Let us, then, see what we can learn about the heating of the air.

HEAT IN THE DRAMA OF WEATHER

How the Air Is Not Heated. We all know that the sun is the furnace that heats our particular corner of the universe. It is the furnace that heats the air. We do not all

know, on the other hand, that the sun does not heat the air directly. The rays of the sun are really not heat at all. They are radiant energy which passes through the air without heating it. Only when the rays strike the earth or objects on it is this radiant energy changed to heat.

A few simple observations will show how objects are heated by radiation from the sun. Our automobile has been standing in the sun of a summer day. Getting in, we rest our bare arm on the metal frame of the window. We jerk back quickly with an "Ouch!" The metal might have just come out of a fire! It was much hotter than the air around it because it, rather than the air, had been heated by the radiation of the sunshine.

We can sometimes notice the same sort of thing in winter. The thermometer on the porch may show 25° above zero, which is well below the freezing point of water. Yet the snow that fell on the sidewalk during the night is melting. Because the radiant energy that strikes it is changed to heat, the sidewalk is warm enough to melt the snow even though the air is well below the freezing point of water.

These observations strongly suggest that the air is not heated directly by the rays of the sun. How, then, *is* it heated?

How the Air Is Heated. Is it not obvious that if the air is not heated directly by the rays of the sun, *it must be heated by the surface on which it rests*? Such, indeed, is the case. Sunshine guards well its gift of warmth through all its long journey in space. Not until it reaches the surface of the earth does it lay down its precious burden. The lands and the oceans absorb radiant energy, changing it to heat, and later giving some of this heat to the air.

Three different kinds of heat movement take part in this heating of the air. Possibly you already know about these from earlier work in science, but it will do no harm to review them very briefly here.

Radiation. Radiant energy, as we have just seen, is transferred through a process called *radiation*. This is one of the most common processes in nature. Every time you warm yourself by a fireplace or bonfire, you illustrate the process of radiation. All hot objects radiate energy. The rays of energy turn into heat when they strike a solid or liquid object. Air, which generally contains only a small percentage of solids and liquids in the form of dust and moisture, turns very little radiant energy into heat. That is why the radiant energy from the sun passes, for the most part, through the air to the lands and oceans beneath it.

Conduction. The lands and oceans, which have been heated by radiation from the sun, give off some of this heat to the air above them largely by a process called *conduction*. This too is a very common process in nature. We illustrate it every time we stir a hot liquid with a metal spoon. The part of the spoon which is in the liquid absorbs some of the heat from the liquid, as though it were a sponge absorbing water. The heat then travels up the spoon, from the warmer to the cooler portions. Finally the entire handle becomes warm, even though it is not in the liquid.

The lands and waters of the earth give some of their heat to the air above them by conduction. The heat is then carried higher and higher in the air, partly by conduction but largely by an entirely different process. Let us see what this third process is.

How many types of heat movement are illustrated here?

Convection. Almost everyone has observed that warm air rises and that cold air sinks. A few simple exercises will illustrate these facts.

Exercises. How to prove that warm air rises: Place a feather or a small piece of tissue paper in the warm air over a stove, radiator, or hot-air register. Do light objects rise or fall in a current of warm air? Does warm air rise or sink?

How to prove that cool air sinks: In winter when the heat is on, place a thermometer on the floor, wait five minutes, and then read it. Get on a stepladder and take a temperature reading as near the ceiling as possible. Is it warmer near the floor or near the ceiling? Does cool air rise or sink?

The reason that warm air rises is that air expands and becomes lighter when heated. The movement produced when rising warm air is replaced by sinking cool air is called *convection.* Convection is the chief method that we use to heat the air in our houses in winter. It is one of the chief methods that nature uses to distribute heat in the air outside our houses.

The Endless Give-and-take of Heat. The movements of heat are an everlasting robbing of Peter to pay Paul. Heat is continuously escaping from the sun by radiation. Land and water absorb some of this heat during the daytime, when the sunshine is beating upon them. But even while they are absorbing heat they are also losing it. Some heat is being conducted away beneath their surface. Some is being conducted into the air.

Even while the air is taking heat from the land and water by conduction, it is also losing heat by conduction and convection to the air higher up. At the same time heat is changing to radiant energy and is everywhere escaping into outer space by radiation. It is important to know that *though air is not able to gain much heat through radiation, it loses a considerable amount in this fashion.*

At night much heat is lost by radiation, both from the surface of the earth and from the air. It is very fortunate that this is so. If all the heat which the earth has received from the sun had been hoarded, we should all have turned to cinders long ago! But it is equally fortunate that by day much heat is restored. If the earth should ever lose all its heat, we should very quickly freeze as solid as ice!

Do you see now why, in general, the air grows colder and colder away from the surface of the earth? Conduction and convection carry heat up into the air from the

surface of the earth. This heat is spread thinner and thinner as it is carried farther and farther from the surface. That is why we can have snow peaks on the equator and sub-zero temperatures above Chicago in July.

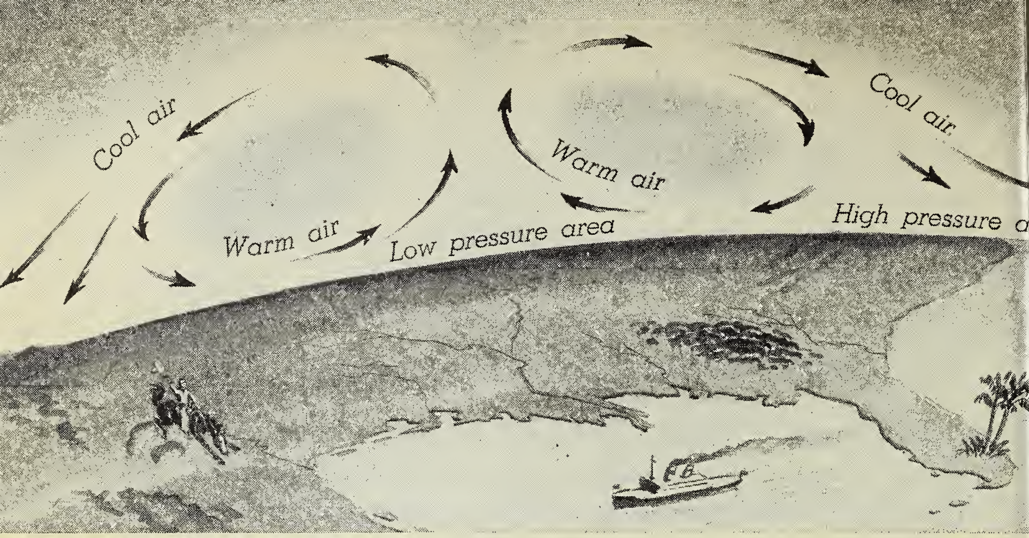
WIND IN THE DRAMA OF WEATHER

The Unequal Heating of the Air. The sun's precious gift of heat is not shared equally by all the regions of the earth. The region around the equator receives far more heat than we do, and the regions around the poles receive far less. Temperature also varies with the seasons. These inequalities in the heating of the earth's surface are important in the production of weather because temperature variations in themselves are an important part of weather. But *temperature variations are also important because they are the major cause of the winds.*

What Is Wind? When heated air expands, becomes lighter, and rises from the surface of the earth, cold air rushes in to take its place. Where light warm air is rising there will naturally be *less* than average air pressure on the surface of the earth at that place. Such a place is known as an *area of low pressure.*

As the warm air rises it becomes cooler and gradually contracts and sinks. Where heavy cold air is flowing toward the ground there will naturally be *more* than average air pressure at that place. Such a place is known as an *area of high pressure.*

The drawing on page 98 shows how areas of low and high pressure are produced. Study it carefully. Such areas are produced locally in many places. We shall study them in detail later.



How areas of low and high air pressure are produced

Wind is merely air in motion. Most winds are produced by the rushing of air from places of high pressure to places of low pressure. They blow until the pressures have become the same.

The Upper Limits of Convection. It is obvious that rising air can rise only so far and no farther. As warm air rises it cools, and as it cools it contracts and gets heavier. In time it gets so heavy that it can rise no higher. Above the altitude where convection stops there is little movement of the air and little change in temperature.

Do you see now why the stratosphere is so evenly still and cold? It is a region of dead air, a region without convection.

Over the equator, where the sunshine is hottest and convection currents are strongest, warm air rises much higher than it does in the temperate and frigid zones. Do you see now why the stratosphere begins at ten miles above the torrid zone, at seven miles above the temperate zones, and at five miles above the frigid zones?

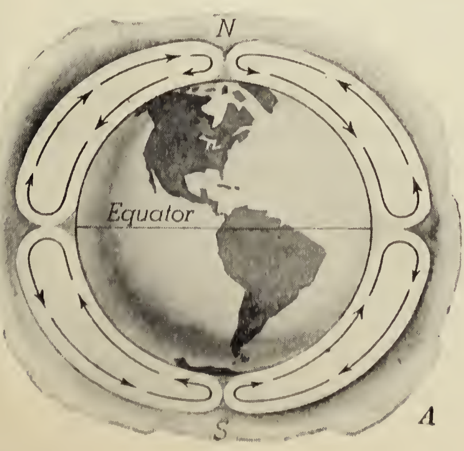
Belts of High and Low Pressure. Because the equator is always warmer than the poles, *warm light air is always rising from the equator and flowing toward the poles.* At the same time *cold heavy air is always sinking and flowing toward the equator.* The drawing at *A* below shows how the air tends to move between the equator and the poles.

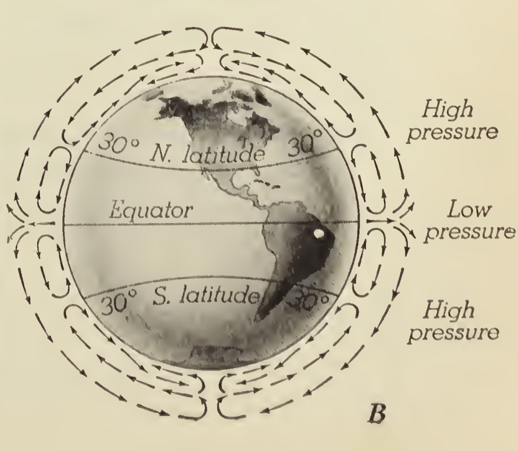
The actual movement of the air between the equator and the poles, however, is not so simple as the arrows in *A* would suggest. Near 30 degrees north and south latitudes the cold polar air which is flowing equatorward meets the warm equatorial air which is flowing poleward. Study *B* and see what happens.

Notice particularly that the air currents are forced sharply downward at 30 degrees north and south latitudes to produce belts of high pressure. *Belts* of high pressure extend completely around the earth. They shift somewhat with the seasons, but they never disappear. *Areas* of high pressure are much smaller than belts of high pressure. As we shall see in a later chapter, they come and go as local conditions change.

Exercise. How you could know from the drawing at *B* below that air pressure was high in the belts of high pressure even if they were not labeled: Study the arrows

How belts of low and high pressure are produced





carefully and review the section "What Is Wind?" Notice also that over the equator lies a "belt of low pressure." Can you tell why? If you are not sure of your answer, review the section "What Is Wind?" again.

The Prevailing Winds. The winds produced by these great belts of high and low pressure are very steady in both direction and speed. They are called *prevailing winds* because they are so steady. The drawing on the opposite page gives the names of the important prevailing winds. Notice that they do not blow straight north and south as you might have expected. *The rotation of the earth turns the winds in the torrid zone toward the west and those in the temperate zones toward the east.*

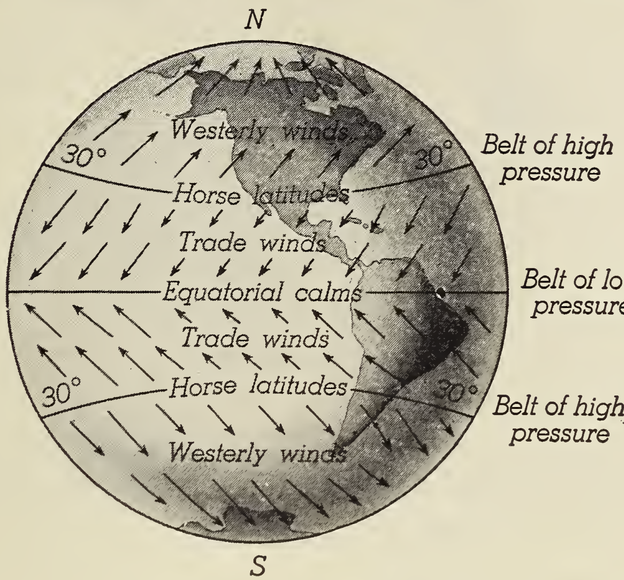
The prevailing winds form the pattern on which the entire circulation of the air is based. Special local conditions, however, are continually changing the pattern in any given place. The ever-changing amount of moisture in the air is perhaps the chief reason for local changes in the circulation of the air. We cannot understand the weather until we understand what moisture does to the air.

MOISTURE IN THE DRAMA OF WEATHER

Water Vapor Is Lighter than Dry Air. You will probably remember from your earlier work in science that water is continually changing into water vapor by evaporation. Have you ever wondered what this vapor does to the air?

Exercise. Go to the kitchen and watch a pot of boiling water. Is steam present? If so, is the steam rising or falling in the air?

This simple observation will prove that water vapor is lighter than air because the steam consists of little drops



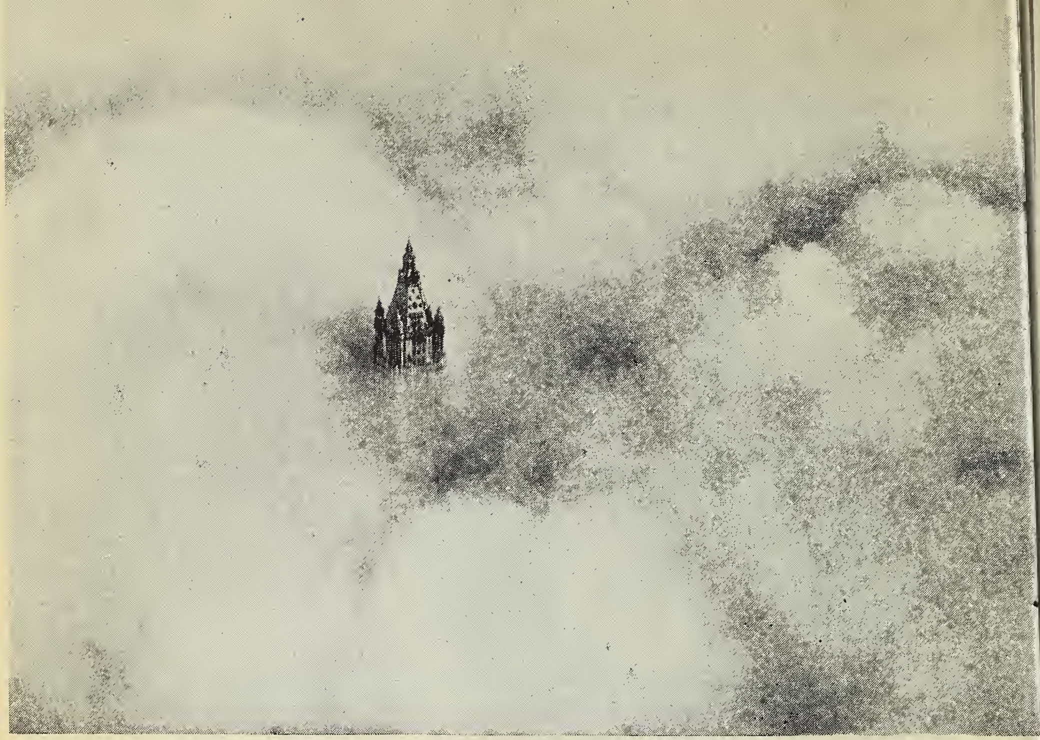
The prevailing winds and how they blow

---

of water which formed from the water vapor that rose from the pot. By actual weight *water vapor is only five eighths as heavy as dry air.*

Is Moist Air Heavier or Lighter than Dry Air? You might think at first that when water vapor is added to air, it naturally makes the air heavier. Is it not reasonable to assume that if we add something with weight to something else, we increase the total weight?

The truth is, however, that when water vapor mingles with dry air, the air becomes lighter. The water vapor is not *added* to the air in the sense that its weight is added to the weight of the air. The water vapor in the air makes



Fairchild Aerial Surveys

Here is how a fog over a city might look to a passing bird

room for itself by shoving aside some of the heavier gases of which the dry air is composed. As a result, the more moisture air absorbs, the lighter it becomes.

How Moisture Affects Air Pressure. All moist surfaces give off water vapor to the air. Some, however, give off much more than others. A large lake, for example, gives off more moisture than a meadow. We say that the air over the lake has a higher *humidity,* which means that it contains a larger percentage of moisture. As a result, the air over the lake is lighter than the air over the meadow.

Can you see, then, how water vapor causes air pressure to vary from place to place? Like varying temperatures, varying amounts of moisture cause areas of higher and lower pressure in the air. In each case the lighter air rises

and the heavier air moves in to take its place. *Thus differences in the amount of moisture in the air, like differences in the temperature, may result in winds.*

Winds, of course, are never produced entirely by differences in temperature or entirely by differences in the moisture content of the air. Heat and moisture always work together. In some cases the one does more of the work, and in some cases the other. But neither heat nor moisture ever stops working. Together they keep the lower air forever on the move.

How Moisture Returns to the Earth. The water vapor in the air does more than help produce the winds. It helps produce many other kinds of weather conditions. Water vapor is very unstable. It is continually turning back into water and returning to the surface of the earth. When

Rain is the commonest type of precipitation

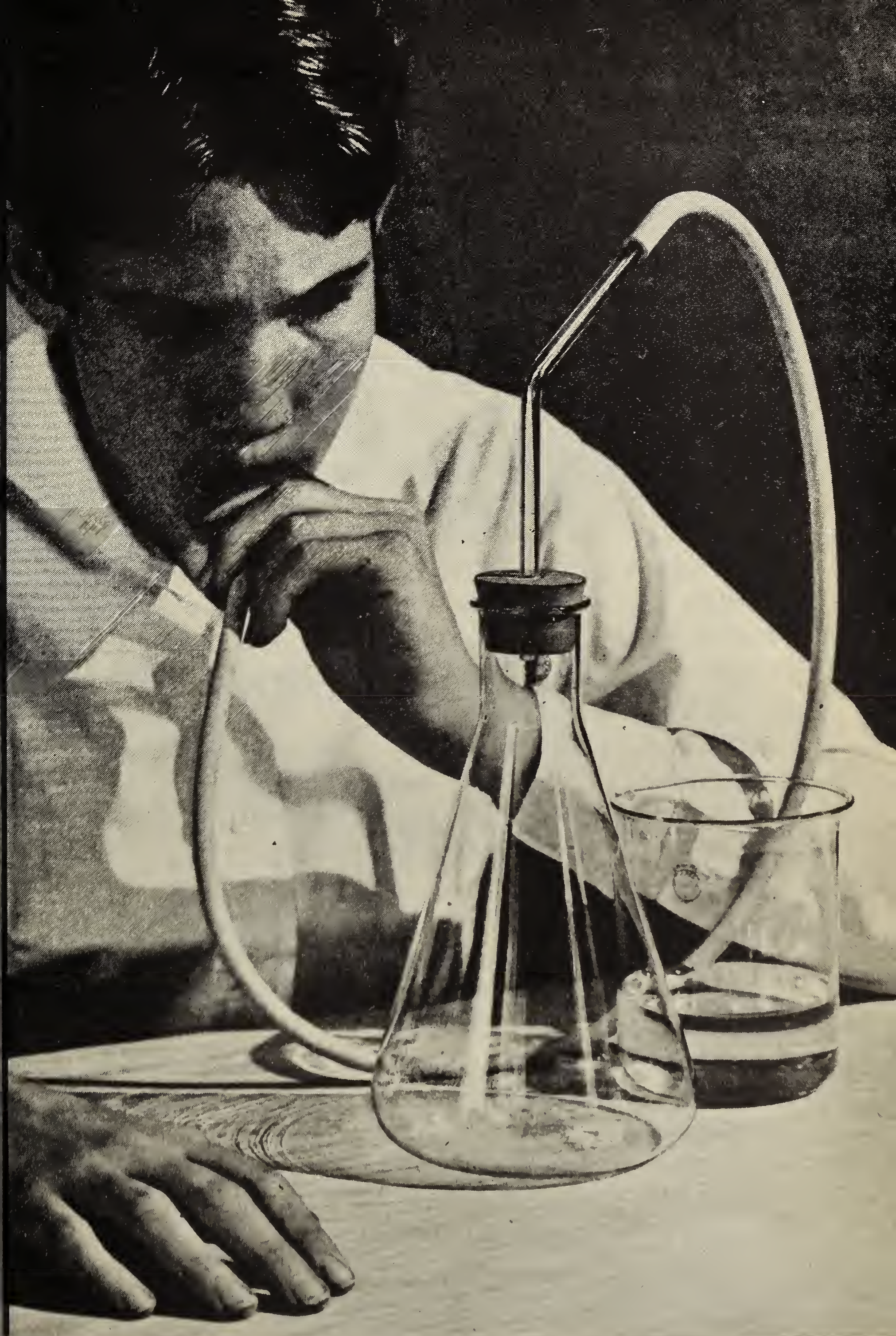
water vapor turns back into water, the process is called *condensation.* When condensed water vapor falls from the air to the surface of the earth, we call the process *precipitation.*

From your observation on boiling water you know that water turns into water vapor when it is heated. You might expect that it would turn back into water on being cooled. This, indeed, is exactly what happens. *Cooling of the air is the chief cause of condensation and precipitation.*

Clouds and Fogs. Sometimes the moisture of the air condenses in particles of water so tiny that they are not heavy enough to fall to the ground. Billions of such particles may hang in the air and produce a *cloud.* When the drops of moisture in a cloud are near the surface of the earth, the cloud is called a fog. A *fog* is thus merely a cloud which is resting on the surface of the earth. Passing through a cloud in an airplane, even though high in the air, is like passing through a fog.

Exercise. How to demonstrate the formation of clouds: Place a little water and chalk dust in the bottom of a glass flask. Insert one end of a bent glass tube in a stopper and fit a piece of rubber hose over the other end. Put the stopper as tightly as possible in the neck of the flask, as shown on the opposite page. Next blow air into the flask and squeeze the rubber hose to hold it there. Release the air suddenly and an artificial cloud will take form in the flask.

Who has not watched the clouds as they drift and change their shapes in the sky? You have probably noticed that there are several different kinds of clouds. But have you ever studied the differences and wondered what they mean?



This boy is making an artificial cloud

The Kinds of Clouds. Have you ever noticed the thin wispy clouds pictured at the top of the opposite page? Such clouds are sometimes called "mare's-tails." Do you see why? The scientific name for these clouds is *cirrus*, which means "a curl of hair." Cirrus clouds sail higher than all other clouds, five miles or more above the surface of the earth. They are made up entirely of tiny crystals of ice. Can you tell why? When they gather in front of the sun or moon, they produce the interesting "rings" which we sometimes see around these heavenly bodies.

Far lower, about a mile above the surface of the earth, are clouds that look like great soapsuds in the sky (see the middle picture). These are known as *cumulus* clouds, which means "a pile" or "a heap." Cumulus clouds are most common in summer. They are formed locally where warm currents of air are rising and cooling until their moisture begins to condense.

When cumulus clouds grow large and darken into a "thundercloud," they are known as *nimbus*, or "rain," clouds. Sometimes these clouds grow to the astounding height of three miles before they break up in rain. Nimbus clouds sometimes have beautiful edges of brilliant light. The ancients thought that when the gods came to earth they came clothed in nimbus clouds. The brilliant edging of such a cloud was thought to be a halo for the god within.

Dew, Frost, Rain, Hail, and Snow. When water vapor condenses out of the air, it may do so in two different ways. First, it may condense directly on objects at the surface of the earth. Second, it may condense higher up and then later fall to the surface. The first may result in dew or frost, the second in rain, hail, or snow.

If the temperature of the land, or of objects on it, falls

Cirrus clouds
are
delicate and
wispy

Cumulus clouds
are
bright and foamy

Published by McGraw-Hill Book Co.

From Gayle Pickwell, *Weather*

Nimbus clouds
are dark
and threatening

below the temperature of the surrounding air, the moisture in the air may condense at the surface of the earth as *dew*. (We shall learn more about this process in the next chapter.) If the temperature of the air at the surface of the earth falls below the freezing point of water, the moisture in the air may condense on cold objects as *frost*.

When particles of moisture high in the air become heavy enough to fall, the result is *rain*. If rain passes through a layer of cold air before reaching the earth, it is apt to freeze and be precipitated as *hail*. If all the air in a given region is cold, its moisture may be precipitated on the earth as *snow*.

Notice that *each one of these forms of condensation is determined by a special temperature condition*. This illustrates again the partnership of temperature and moisture in producing the varied display of weather.

Weather Is the Result of Many Things. Do you see that weather is a drama in which temperature, wind, and moisture play the leading parts? Do you see that it is a drama which never ends, and one in which the plot is forever changing? Yet with all the changes and uncertainties of weather, it is possible to know something about it in advance. Accurate weather prediction is one of the great triumphs of civilized man. Let us see how this triumph is won.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. One of the great achievements of civilized man is that he has learned how to change the weather to suit his needs

2. Observations from balloons have proved that storms in the upper air are far more severe than storms in the lower air.

3. It is now definitely known that temperature falls regularly and steadily with height above the surface of the earth until the intense cold of empty space is reached.

4. The rays of the summer sun heat the air intensely as they travel toward the surface of the earth.

5. Radiation, conduction, and convection are all important methods of distributing heat in the air, but radiation is much the most important.

6. Areas of low pressure are produced at night when air loses heat by radiation and grows lighter.

7. There is a belt of calms around the equator because the hot tropical air is stagnant and almost never moves.

8. Winds are entirely controlled by local conditions.

9. The direction of the prevailing winds makes it much easier to fly from London to New York than from New York to London.

10. When water enters the air by evaporation, the air becomes heavier.

11. Heating of the air is the major cause of condensation and precipitation.

12. Cumulus clouds differ from all other clouds because they are made up entirely of tiny crystals of ice.

13. Rain falls when enough moisture accumulates in the air, and is not affected by the temperature of the air.

Questions for Discussion

1. What do you conclude is the chief cause of the *regular* changes of temperature in your locality? of the *sudden* changes?

2. Discuss the winds of your locality and try to determine if there is any regular relationship between the direction of the wind and the weather.

3. What form of precipitation is commonest in your locality? When does it occur? Why does it occur as it does?

4. Make a list of the things you like about the weather of your locality and discuss it with your classmates.

Things to Do

1. Ask your teacher where you may find the stories of some recent flights into the stratosphere. Read them and write a report on them for your class.

2. From a map of the world's principal wind belts determine in what region of the world a sailing vessel could really be "blown around the earth" by the prevailing winds. Do you think this might be important to the future development of aviation?

3. Today most of the world's ocean trade is carried on by steamships. Only a few sailing vessels are left. If you want to know about life on one of these, read Villiers' *Falmouth for Orders*. A similar account appears in the *National Geographic Magazine* for January, 1933.

4. A fine story of life in the sailing ship of days gone by is found in Dana's *Two Years before the Mast*. You may not want to read all of it, but some parts are very good. Read it and report on it in class.

5. In Alexander McAdie's little book called *Man and Weather* you will find many interesting stories of how weather has influenced the actions of men in war and peace Select a few of these to tell to your class.

CHAPTER FIVE

How Does the Weatherman Study the Weather?

WEATHER PROPHETS

False Signs. We cannot change the weather to suit our tastes, but we can do the next best thing. We can know about the weather a little in advance and can prepare ourselves to meet it. The ability to predict the weather saves us millions of dollars and many lives each year.

We call the men who perform this service the "weathermen." They are stationed all over the country, and they make up a branch of the government known as the Weather Bureau. Like a doctor who feels the pulse of a patient, the weatherman feels the pulse of the air. It is his business to learn from what the air is doing today what it is likely to do tomorrow.

Prediction of the weather is far older than the Weather Bureau. Men have always been interested in weather and have always tried to know about it in advance. There are many signs which people have used for many years to predict the weather. Unfortunately, many of these signs are false. Belief in them is not science but superstition.

There is, for example, no evidence that it is more likely to storm during one phase of the moon than during another. If it happens to rain on Easter, there is no reason to think that it will rain for the next seven Sundays. The ground hog may or may not see his shadow on Ground Hog Day—but one way or the other it does not affect the weather. The heaviness of the fur on animals and the heaviness of

the husk on an ear of corn are not, as many people believe, reliable guides to the severity of the coming winter.

There are people in every community who believe that they can accurately predict cold winters and hot summers, but there is no reason to believe that such predictions will certainly come true. If a man makes a prediction which by chance *does* come true, everyone remembers it. He becomes at once a good "weather prophet." As you study the work of the Weather Bureau in this unit you will learn that *predictions for more than a few days in advance are extremely uncertain.*

Even in this scientific age, "rain-makers" make good livings out of ignorant people. They may use prayers or dances to bring down the rain; they may use some secret mechanical device; or they may simply act in a mysterious manner. In any case their mumbo jumbo is of no more value than the rain-making ceremonies of savages (see illustration below).

This dance of the Zuñi Indians is a prayer for rain

Ben Wittick Collection, Laboratory of Anthropology, Santa Fe

True Signs. There are, to be sure, a few weather signs that are trustworthy. Have you read "The Wreck of the Hesperus," by Longfellow? There is a passage in that poem which reads as follows:

> Then up and spake an old Sailòr,
> Had sailed to the Spanish Main,
> "I pray thee, put into yonder port,
> For I fear a hurricane.
>
> "Last night, the moon had a golden ring,
> And to-night no moon we see!"
> The skipper, he blew a whiff from his pipe,
> And a scornful laugh laughed he.

The skipper chose a poor time to laugh. A ring round the moon, as illustrated below, is frequently seen before a storm. Such a condition shows that moisture in the air is condensing in little droplets, which look like a ring when they lie directly between us and the moon. Such a ring is really a very trustworthy prediction of rain or snow.

When the sun sets clear, you may rightly expect that the following day will be fair. When the sun sets behind a cloud, the next day may well be stormy. These observations have real meaning. We live in a westerly-wind belt, as the diagram on page 101 shows. It is likely that the weather conditions in the direction of the sunset will move toward us with the wind from the west.

A ring round the moon means that moisture is condensing in the air

Exercise. Here are some sayings about the weather. Probably you can add many more. Do you think any of these have real meaning, or are all of them mere superstitions?

Rainbow in morning, sailors take warning;
Rainbow at night, sailors' delight.

If rain falls on St. Swithin's day, it will rain for the next forty days.

A dog eating grass is a sign of rain.

If it rains before seven, it will clear before eleven.

The Best Prophet. The weather forecast printed in the newspaper is much more dependable than any of the weather signs. The official forecast is based upon many observations, all of which are taken with scientific accuracy. *The Weather Bureau has a record for accuracy in about 80 per cent of its predictions.* There are many jokes about the failures of the weatherman. He does fail at times, but generally only in minor matters. People, however, tend to remember his failures rather than his successes.

Exercise. Each morning clip from the daily paper the weather forecast for the day and paste the clippings in your notebook. After the day has passed, write a description of the kind of weather that actually came Continue this for ten days. Are the predictions of the Weather Bureau dependable?

HOW THE WEATHERMAN STUDIES TEMPERATURE

Stations of the Weather Bureau. The weathermen study the conditions that determine the weather. They study very carefully the temperature, pressure, and moisture of

t every dot on this map weathermen make the observations which form
the basis of the weather forecasts that appear in your daily paper

the air and the direction and speed of the wind. Weathermen are located in stations which are scattered over the whole continent of North America, as well as on islands and on ships at sea. The Russian government has recently established a station at the north pole.

Examine the map on page 115. Early every morning (8 A.M. Eastern Standard Time) the reports of the weathermen in all these stations are sent to a few central stations. There weather forecasts are made for periods ranging from thirty-six hours to a week. These are the forecasts you read in the daily papers.

If you have ever visited a station of the Weather Bureau, you may have seen some of the equipment which is used to study the weather. If you have never visited such a station, look at the photograph on the opposite page. In it you may see the most important instruments used by weathermen in studying the weather. There are thermometers for measuring temperature, barometers for measuring air pressure, instruments for measuring humidity and for determining the speed and direction of the wind.

The accuracy of weather predictions depends to a considerable extent on the accuracy of such instruments as these. Let us see if we can learn how they are used.

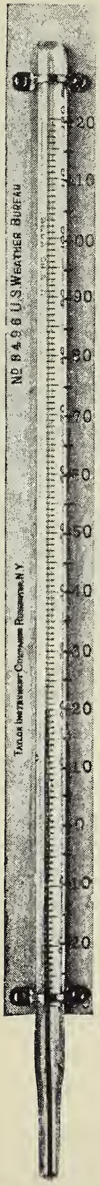
The Mercury Thermometer. In the last chapter we learned about the great importance of heat in the drama of weather. We learned that the air is unequally heated by the sun, and that this is one of the chief causes of the winds. The weatherman must therefore pay particular attention to the temperature of the air. He must record its changes, not only because they make up an important part of today's weather but also because they help him foretell what tomorrow's weather is likely to be.

U. S. Weather Bureau

The accuracy of weather predictions depends on the accuracy of these instruments and men

The instrument he uses for this purpose is the familiar mercury thermometer shown on page 118. It is simply a hollow glass tube with a bulb full of mercury at the lower end. You may remember from earlier work in science that mercury is a material which expands greatly when heated and contracts greatly when cooled. Its movement up and down within the glass tube gives an accurate picture of the changes in temperature of the air outside the tube.

How Mercury Thermometers Are Made. In making a mercury thermometer, the end of the tube away from the bulb is left open. The mercury in the bulb is then heated gently until it rises and begins to flow out of the open end. In this way the air is forced out of the tube. Then, at a



The mercury thermometer measures temperature

temperature a little above the boiling point of water, the open end of the tube is heated in a flame until the glass melts. When the glass cools and hardens, it seals the tube. The mercury can now move up and down in its air-tight prison as the temperature changes.

The tube is next placed in ice. As it cools down to the temperature of the ice, the column of mercury falls to a certain position and then does not fall any farther. This is the freezing point of water and is marked with a scratch on the glass of the tube opposite the top of the column of mercury. If the centigrade scale is used, as in the thermometer shown on the left, the scratch is labeled 0. If the Fahrenheit scale is used, the scratch is labeled 32.

Next the tube is placed in boiling water, and the column of mercury rises to, and holds a position which marks, the boiling point of water. This position is scratched on the glass and labeled 100 for a centigrade thermometer or 212 for a Fahrenheit thermometer.

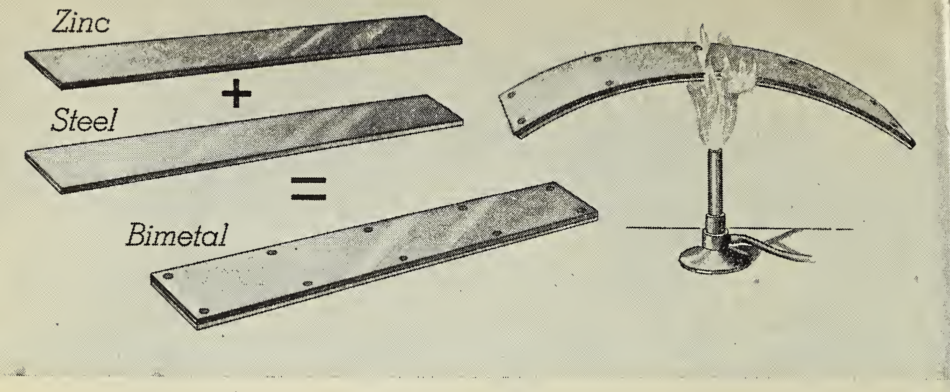
The distance along the stem between these two scratches is divided into 100 divisions, or *degrees*, for the centigrade scale, or 180 divisions for the Fahrenheit scale. Scratches are also made below the freezing point and above the boiling point in order to register temperatures below the freezing point and above the boiling point of water. After the glass stem is marked in this way the thermometer is ready for use.

This girl is testing the accuracy of a mercury thermometer

Exercises. How to test a thermometer to see if it has been accurately marked: Cover the bulb of a thermometer with crushed ice, as shown above. Leave it until the mercury will go no lower. Has the freezing point been accurately marked? Test two or three thermometers such as may be obtained from a ten-cent store.

Place the bulb of a thermometer in a pan of water. Heat the water until it boils and then continue heating for a few minutes. Has the boiling point been accurately marked?

The Metallic Thermometer. Another type of thermometer is useful because it may be mounted so as to give a continuous record of changes in temperature. Inside this kind of thermometer there is no liquid mercury. Instead there are two solid strips of metal securely riveted together to make a bar.



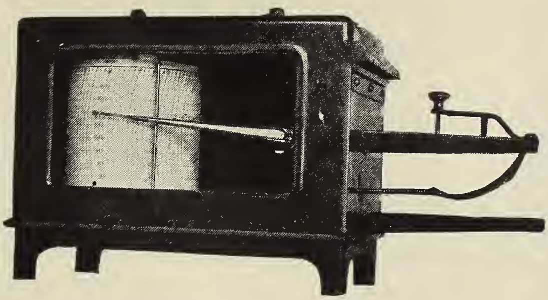
How to make a compound bar

One of these strips may be made of zinc and the other of steel. These metals, like mercury, expand when heated and contract when cooled, but *zinc expands and contracts considerably more than steel.* As the temperature rises, the greater expansion of the zinc causes the bar to bend into a curve. As the temperature falls, the greater contraction of the zinc causes the bar to bend back again. The end of the bar is connected with a pointer. As the bar curves and straightens, the pointer moves back and forth on a dial. The figures on the dial correspond to the figures on the stem of a standard mercury thermometer.

Exercise. How to demonstrate the effects of change of temperature on such a "compound bar": Rivet a strip of zinc to a strip of steel, as shown above. Your science teacher will help you do it. Use strips about one foot long. After you have made the compound bar, hold it in a flame for a few seconds. The heat will cause the bar to bend. The direction of the bend is such that the zinc is on the outside of the curve. Why?

The Thermograph. A metallic thermometer fitted with a pen instead of a pointer can be made to keep a continuous record of temperature changes. A cylinder which turns by

clockwork is covered with ruled paper and adjusted so that the pen will make a continuous mark on the paper. As the

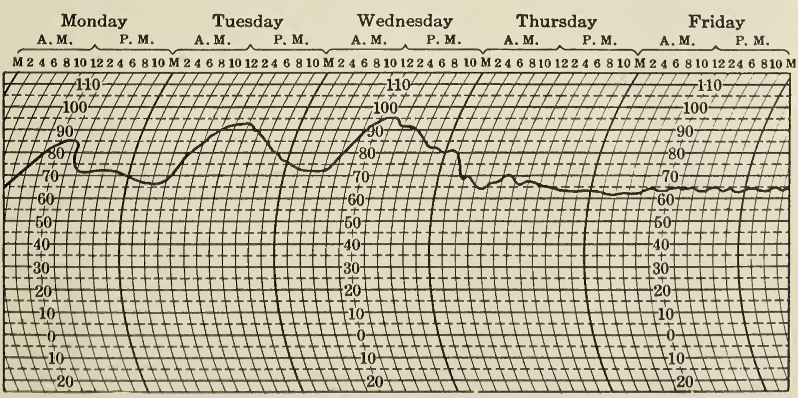


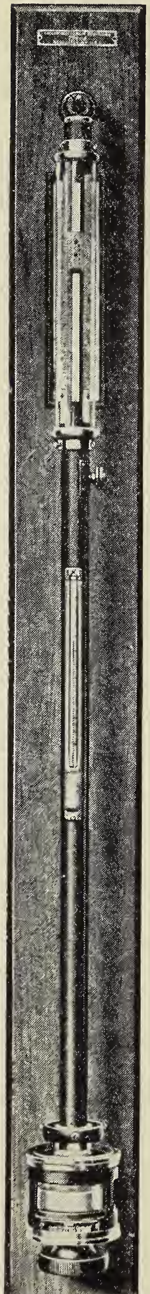
The thermograph keeps a continuous record of temperature conditions

pen moves back and forth with changes in temperature, the line it makes on the turning paper moves up and down. In this way a continuous temperature record may be kept.

Such an instrument is called a thermograph ("heat-writer"), and is pictured above. Below you may see a thermograph record of temperature changes which took place during a period of five days.

The thermograph record tells the story of changing temperature





Mercury thermometers and thermographs are used every day in every station of the Weather Bureau. Without them weather forecasting would be impossible.

HOW THE WEATHERMAN STUDIES AIR PRESSURE

The Mercury Barometer. In the last chapter we saw that the winds are produced when air rushes from places of high pressure to places of low pressure. Wind is a very important part of weather; so the weatherman must make careful observations on the differences in air pressure which cause it. He makes these observations with the help of the barometer ("measurer of weight").

As its name indicates, the barometer measures the weight, or pressure, of air. A common type of barometer is shown at the left. It is called a mercury barometer. It consists of a glass tube at least 34 inches long which has been sealed at one end, filled with mercury, and then turned upside down with the open end in a cup of mercury. Air pressure on the mercury in the cup prevents the mercury in the tube from running out. The height at which the mercury stands in the tube is therefore a measure of the pressure of the air.

You may have made a mercury barometer in connection with earlier work in science, but

The mercury barometer measures air pressure

This homemade mercury barometer measures air pressure fairly accurately

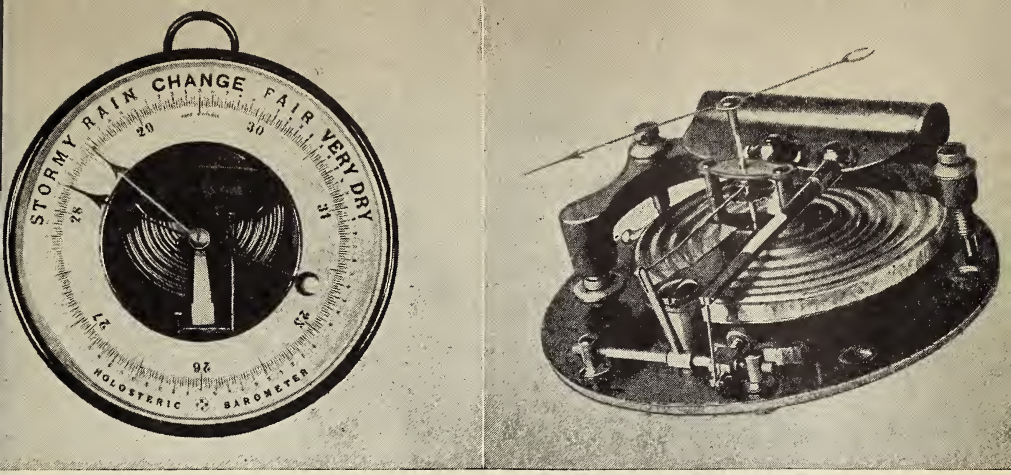
it will do no harm to repeat the experiment here. If you have never made a mercury barometer, you may want to know exactly how this useful instrument works.

Exercise. How to make a mercury barometer: Secure a piece of glass tubing 34 inches long and sealed at one end, a bottle of mercury, a small dish to hold the mercury, a clamp, and a ring stand (see page 123). Completely fill the tube, and partly fill the dish, with mercury. Place your thumb firmly over the open end of the tube and turn it upside down in the dish of mercury. In doing this be careful not to allow air to enter the tube. Fasten the tube in an upright position to the ring stand by means of the clamp. After the tube has been set in place, some of the mercury runs out into the dish until the pressure of the mercury in the tube just balances the pressure of the air on the mercury in the dish. When you measure the height of the mercury column, you will probably find it a little less than 30 inches, and you will find that its height varies a little on different days.

Air pressure is generally about 15 pounds per square inch at sea level, but we commonly speak of air pressure in terms of inches. When we say that the air pressure is 29 inches, we mean that the air will support a column of mercury 29 inches high.

Scientists use another way of expressing air pressure. For certain reasons they base this way of measuring on a mercury column 29.5306 inches high. This they call 1000 millibars. Pressure at any time and place is then given in millibars—say 956 or 1016, and so on.

The Aneroid Barometer. Another type of barometer, known as the aneroid barometer, is illustrated on page 125. This instrument is quite unlike the mercury barometer,



'he aneroid barometer measures air pressure through an expanding and contracting metal box

but it is used for the same purpose. Inside the case of an aneroid barometer is a disklike metal box which has been tightly sealed after most of the air has been removed. The illustration shows such a barometer with the cover in place and also with the cover removed to show how the instrument works.

When air pressure increases, the sides of the box are pushed a little inward. When air pressure is lessened, the sides of the box bulge a little outward. The effect of these changes is carried to the pointer on the face of the barometer by means of levers. The pointer is mounted so that it moves toward the higher numbers on the dial when there is an increase in air pressure. It moves toward the lower numbers when there is a decrease in air pressure. The marks on the dial of an aneroid barometer are made to correspond with those on a standard mercury barometer.

The Barograph. One form of aneroid barometer is known as a barograph. The barograph is used to keep a continuous record of pressure changes just as the thermograph is used to keep a continuous record of temperature changes.

In this instrument a pen moves upward and downward with changes of air pressure, and these changes are automatically recorded just as in the thermograph.

Mercury barometers, aneroid barometers, and barographs are perhaps the most important instruments used by the weatherman in predicting the weather. *Marked changes in air pressure always take place before marked changes in the weather.* It is the problem of the weatherman to interpret changes in air pressure in terms of the approaching weather. How he does this we shall learn in the next chapter.

HOW THE WEATHERMAN STUDIES HUMIDITY

The Dew Point. The humidity, or amount of moisture in the air, is a very important part of weather. We saw in the last chapter that moisture and temperature work together in producing areas of low and high pressure in the air. The weatherman must therefore study humidity just as carefully as he studies temperature and pressure.

The amount of water vapor that any given amount of air can hold depends upon the temperature. As the temperature of the air is reduced, the amount of water it can hold is also reduced. There is always some water vapor in the air; so if the temperature is reduced sufficiently, some of this will condense as dew. The temperature at which moisture begins to condense as dew is the temperature at which the air is said to be saturated (filled) with moisture. *This temperature is called the dew point.*

Exercise. How to determine the dew point of air in your schoolroom: Place a thermometer in a beaker of water, as illustrated on the opposite page. Add small chunks of ice to the water, stirring all the while, and keep adding

ice until a film of dew appears on the outside of the glass. The temperature of the water at the time the dew appears on the outside of the beaker is the dew point of the air in your schoolroom.

Relative Humidity. The amount of water vapor a given quantity of air holds at a given temperature may be stated as its relative humidity. It is called "relative" humidity because it is always expressed as a percentage of the amount of moisture which is required to saturate the air at the given temperature. For example, if a given quantity of air at a given temperature contains only one quarter of the moisture it is capable of holding, its relative humidity is 25 per cent. If the air contains all the moisture it can hold at a given temperature, its relative humidity is 100 per cent.

Warm air can hold more moisture than cold air, but both warm air and cold air do not ordinarily contain as much water vapor as they might. In other words, air is not ordi-

This girl is determining the dew point of the air in her schoolroom

narily saturated. The reason for this is that water vapor is widely scattered in the air. It is forever moving from one place to another. There is not enough of it to saturate all the air in the world at the same time. There is only enough to saturate the air locally from time to time.

It is important in weather forecasting to know how nearly saturated with water the air is. If the relative humidity is low, it is not likely that there will be rain. If the relative humidity is high, it is likely that it will rain. Do you see why?

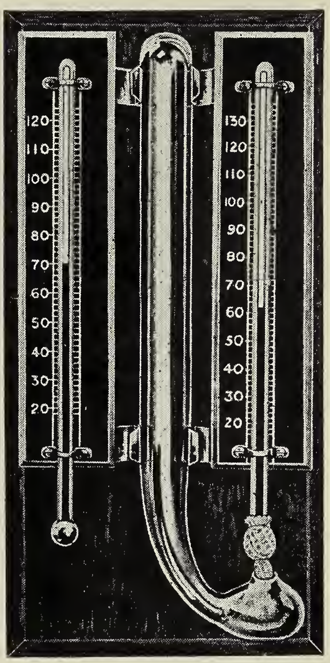
The Wet-Bulb Thermometer. A most useful instrument for determining the relative humidity is the wet-bulb thermometer. An experiment will help you understand it.

Exercise. Tie a piece of cloth around the bulb of a thermometer, as shown on the opposite page. Read and record the temperature by this thermometer. At the same time read and record the temperature of another thermometer that has no cloth on its bulb. Now moisten the cloth on the first thermometer, and after a minute or so read it again. Use a piece of cardboard for a fan and fan the wet cloth for a minute, or hold it before an electric fan. Fan it until the temperature stops changing. Record the lowest temperature of the wet-bulb thermometer. What is the difference between this temperature and the temperature registered by the dry-bulb thermometer?

The above experiment shows that *evaporation causes cooling*. The more rapidly water evaporates, the greater the cooling. Furthermore, the rate at which water evaporates is affected by the amount of water vapor in the air. If the air is very dry, evaporation goes on faster and the cooling is greater. If the air is saturated with moisture, as

These boys are determining the relative humidity of their schoolroom

when it is raining, evaporation does not go on at all, and the temperature by the wet-bulb thermometer will be the same as that by the dry-bulb thermometer. Do you see, then, that the temperature by a wet-bulb thermometer is an indication of humidity?



The wet-and-dry-bulb thermometer measures relative humidity

A common form of wet-and-dry-bulb thermometer is shown at the left. The cloth about the bulb of one of the thermometers is kept wet. The bulb of the other thermometer is dry. The difference between the readings of the wet-bulb and the dry-bulb thermometers helps determine the relative humidity of the air.

Exercise. How to determine the relative humidity of your schoolroom: You have already determined the temperature of your schoolroom by a dry-bulb and by a wet-bulb thermometer. You can use these figures to find out the relative humidity of the room. Study the table on page 131. Find the vertical column headed by the figure which corresponds with the difference in temperature between your dry-bulb and your wet-bulb readings. Look down this column until you come to the horizontal column in which the figure on the extreme left corresponds with the dry-bulb temperature of your room. The figure where the vertical and horizontal columns meet is the relative humidity of your room.

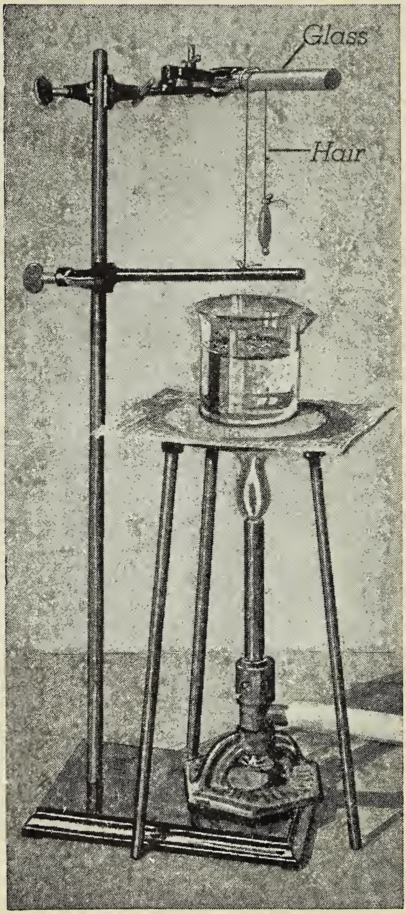
Dry-Bulb Temp.	Difference between Dry-Bulb and Wet-Bulb Temperatures																	
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0
60	94	89	84	78	73	68	63	58	53	49	44	40	35	31	27	22	18	14
61	94	89	84	79	74	68	64	59	54	50	45	40	36	32	28	24	20	16
62	94	89	84	79	74	69	64	60	55	50	46	41	37	33	29	25	21	17
63	95	90	84	79	74	70	65	60	56	51	47	42	38	34	30	26	22	18
64	95	90	85	79	75	70	66	61	56	52	48	43	39	35	31	27	23	20
65	95	90	85	80	75	70	66	62	57	53	48	44	40	36	32	28	25	21
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26	22
67	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	30	27	23
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	31	28	24
69	95	90	86	81	77	72	68	64	59	55	51	47	44	40	36	32	29	25
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30	26
71	95	90	86	82	77	73	69	64	60	56	53	49	45	41	38	34	31	27
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32	28
73	95	91	86	82	78	73	69	65	61	58	54	50	46	43	40	36	33	29
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30
75	96	91	87	82	78	74	70	66	63	59	55	51	48	44	41	38	34	31
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42	38	35	32
77	96	91	87	83	79	75	71	67	63	60	56	52	49	46	42	39	36	33
78	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43	40	37	34
79	96	91	87	83	79	75	71	68	64	60	57	54	50	47	44	41	37	34
80	96	91	87	83	79	76	72	68	64	61	57	54	51	47	44	41	38	35

Hair Hygrometers. Did you know that your hair is not the same length when the air is moist as when it is dry? If you didn't, you can prove it by a simple experiment.

Exercise. Tie a fisherman's "sinker" or some other small weight to a human hair. Pass the hair over a glass rod which is mounted on a stand, as shown on page 132. Fasten the loose end of the hair to a clamp which extends from the stand at a position just beneath the weight. Boil water in a beaker beneath the weight. Does the weight change its position? Does it rise or sink? What effect does the moisture have on the hair?

The principle which you have demonstrated in the above experiment is put to work in the so-called hair hygrometers ("moisture-measurers"). A hair is mounted in such a way

that it moves a pointer over a dial as it expands and contracts with the changing amount of moisture in the air. Figures on the dial are marked to show the relative humidity.



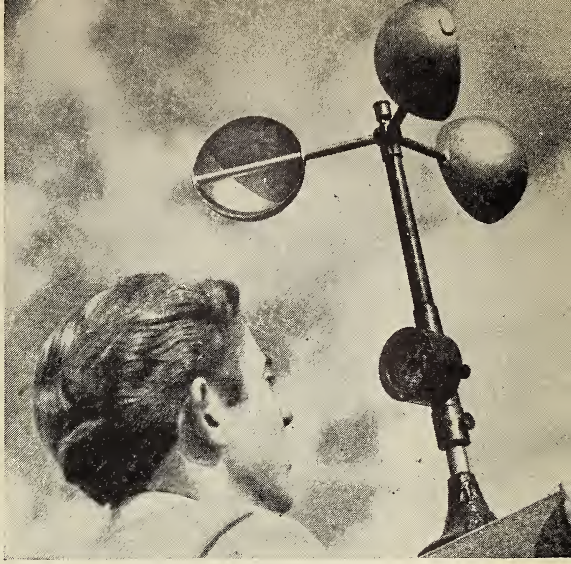
How to show the effect of moisture on a hair

Hair hygrometers may be bought in drugstores. They are not very accurate, but they give a general indication of the relative humidity. The weatherman, however, must have a more accurate instrument; so he uses the wet-and-dry-bulb thermometer.

The Wind Gauge. Wind is one of the chief results of the temperature, pressure, and moisture conditions of the air. We have all seen the weathervanes on houses, barns, and churches, which keep swinging around with the wind. The weatherman has his weathervane, too, because it is very important for him to keep a record of the direction of the wind.

The weatherman also has a wind gauge for measuring the speed of the wind. This instrument is shown on the opposite page. The greater the velocity of the wind, the

This instrument is used to measure the speed of the wind



faster the little cups of the gauge spin round. At each station of the Weather Bureau a gauge of this sort is attached to an electrical instrument which automatically records the wind velocity. The direction from which the wind blows is also recorded automatically. In this way the station can keep a continuous record of wind velocity and wind direction.

How Weather Is Predicted. The predictions of the Weather Bureau are based upon careful observations of the conditions of the air. Observations are made with the very best instruments. *The major conditions of weather are temperature, air pressure, humidity (including clouds and precipitation), wind velocity and direction.* The forecast is a prediction of effects that are likely to be produced from causes which have been carefully studied.

In the next chapter you will learn how the weather conditions in this latitude tend generally to move across the country from west to east. The weatherman knows that the weather which prevails west of his station today is likely to reach his station tomorrow. The accuracy of his predictions depends upon his ability to foretell from records gathered in many cities on one day the conditions that will prevail in his city on the next. The instruments described in this chapter are the ones with which the records are gathered. In the next chapter we shall see how the weatherman interprets these records and makes his predictions.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. The signs used by the ordinary man to predict weather are all untrustworthy.

2. Accurate long-range prediction of weather is the newest achievement of scientific weather forecasting.

3. The jokes about the failure of the weatherman are based on the inaccuracy of 80 per cent of his predictions.

4. If there were no mercury on earth, we should have no way of measuring air pressure and hence no way of making accurate daily weather predictions.

5. The wet-bulb thermometer is used by the Weather Bureau to determine the temperature of rivers and oceans.

6. Dew forms on the grass in the early morning because the sun warms the cool night air and causes it to drop some of its moisture.

7. Air is thirsty for moisture and always contains as much as it can hold at any given temperature.

8. A thermometer wrapped in a wet cloth from which the moisture is evaporating will register a higher temperature than a dry thermometer in the same place, because evaporation develops heat.

9. The weather on Tuesday in Buffalo is apt to be the same as the weather on Monday in Boston.

Questions for Discussion

1. Would you call the weatherman a scientist? Why?

2. How do you think the long-range weather forecasts in an almanac are prepared? How does this differ from the methods used by the Weather Bureau?

3. Do you think the relative humidity of your classroom would vary from day to day? How could you keep it the same?

Things to Do

1. There are many excellent books on the weather. Try Van Cleef's *The Story of the Weather*, or Humphries's *Fogs and Clouds*, or Brooks's *Why the Weather?* A book which is perhaps a little easier to read is Rolt-Wheeler's *The Boy with the U. S. Weather Men.* After you read any of these, tell your classmates whether or not you think they might be interested in reading the same book.

2. Make your own collection of weather signs and superstitions. Be sure to indicate which are only superstitions and which have some scientific basis, and explain why.

3. Have you a weather station in your vicinity? If so, have you visited it? If you make arrangements in advance, the men in charge will probably be glad to have you come. If you cannot visit it, perhaps someone from the station might be glad to come to your school and explain their work. Write and ask about it.

4. As a class, write to the Weather Bureau and ask for its list of publications. You may want some of these.

5. Prepare a booklet on "How the Weatherman Studies the Weather." Illustrate it with drawings or photographs of the instruments used, the types of records kept, and such other information as you think might make your story more interesting and accurate.

CHAPTER SIX

What Is the Nature of the Weather in North America?

CYCLONES AND ANTICYCLONES

The Prevailing Westerlies. The weather of much of North America varies from day to day, but the variations are remarkably regular. Storms and fair weather take turns. Warm spells follow cool spells, and windy days follow calm days. What causes this rhythm in our weather?

From ordinary observations you will probably not notice that the United States and southern Canada lie in the belt of the westerly winds. (Remember that a westerly wind is one that blows *from* the west, and not toward it.) The wind, however, does not always blow from the west. It may blow from any direction. This at first may seem a contradiction, but let us see.

An observation such as the one in the photograph on the opposite page shows that winds blow from the west more often than from the east. These old trees are located on the top of the Continental Divide in Colorado. There are no branches on the western side because lack of protection from the west wind prevented their growth.

Within the temperate zones the air as a whole is continuously moving from west to east, as we learned in Chapter IV. *These general movements are known as the prevailing westerly winds or, simply, the westerlies.* Within the westerlies, however, there may be air currents in any direction. *Such local movements are known as the variable winds.* The variable, rather than the prevailing, winds are


Keystone

Prevailing westerly winds kept branches from growing on the westward side of these trees

the chief cause of changes in our weather. Let us try to see why this is so.

Cyclones. Local differences in temperature and moisture produce local differences in air pressure. The result of this is that areas of low and high pressure develop within the westerly winds. In these areas the air moves in great whirlpools. *Air whirling about a center of low pressure is called a cyclone.*

Some people think of a cyclone as a great and unusual storm which uproots trees and blows the roofs off barns. In the language of the Weather Bureau destructive storms are called tornadoes or hurricanes. Ordinary cyclones are neither severe nor rare. These great masses of whirling air are regular happenings in the regions over which the

This man is making a weather map

prevailing westerlies blow. The Weather Bureau determines their position and charts them on a map every day.

Weather Maps. On page 140 is a simplified drawing of one of these so-called weather maps. Notice the little circles that pepper the face of the map. Each one marks a station of the Weather Bureau. The map was made from information about air pressure, temperature, wind, and precipitation which was gathered at the various stations. Each day such information is collected and put together on a weather map.

Notice the heavy curved lines. Such lines are present on all weather maps, and they contain very valuable information. They are drawn through places of equal air pressure and are known as *isobars*. This is a good name for them, because "iso" means "equal" and "bar" means "pressure." On government weather maps dotted lines (*isotherms*) are

drawn through places of equal temperature. The isotherms were left out of the map on page 140 to make easier the interpretation of the more important isobars.

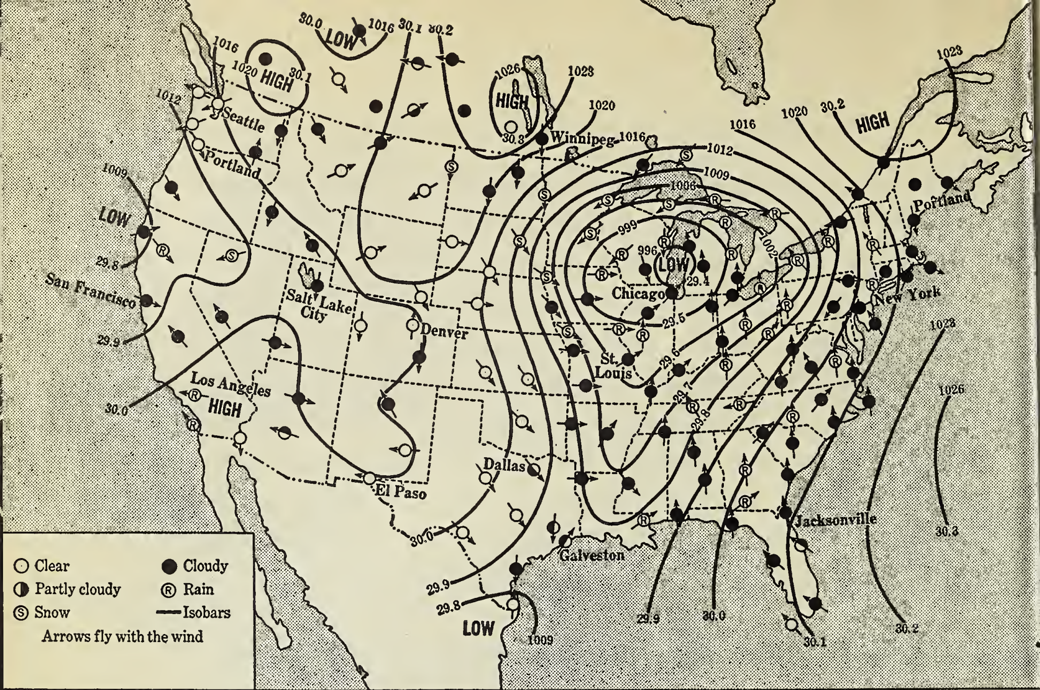
Notice also the arrows which tell the direction of the wind. Notice that the circles through which the arrows are drawn tell whether it is raining, snowing, cloudy, or clear. *R* means rain, *S* means snow, the blackened circle means cloudy, the half-blackened circle means partially cloudy, and the white circle means clear. With the information of the weather map before us, let us see if we can tell how the weatherman makes his forecast.

Exercises. How a weather map helps to predict the weather: Study the weather map on page 140. What is the air pressure near Chicago? directly north of Chicago, in Canada, above Lake Superior? directly south of Chicago near the Gulf of Mexico? What is the air pressure directly east of Chicago on the Atlantic coast? directly west in central Nebraska? Do you see that the low-pressure area, or cyclone, extends from the Gulf of Mexico beyond the Great Lakes, and from the Atlantic Ocean almost to the city of Denver? In what direction is the cyclone probably moving?

What is the wind direction over Iowa? over Missouri? over Ohio? over Lake Superior? Would you say that the wind in this cyclone moved in a direction similar to that of the hands on a clock or in the opposite direction?

Where, with reference to the center of lowest air pressure, is the region of rain? Does rain come with a south wind (wind from the south) or with a north wind? Can you see why? Where is the region of snow, and how is it related to the direction of the wind?

If this was the map of January 10, what weather would you predict for Chicago for January 11? Will it be cloudy or clear? What will be the direction of the wind?



This weather map shows the air pressure, wind, and moisture conditions in a cyclone

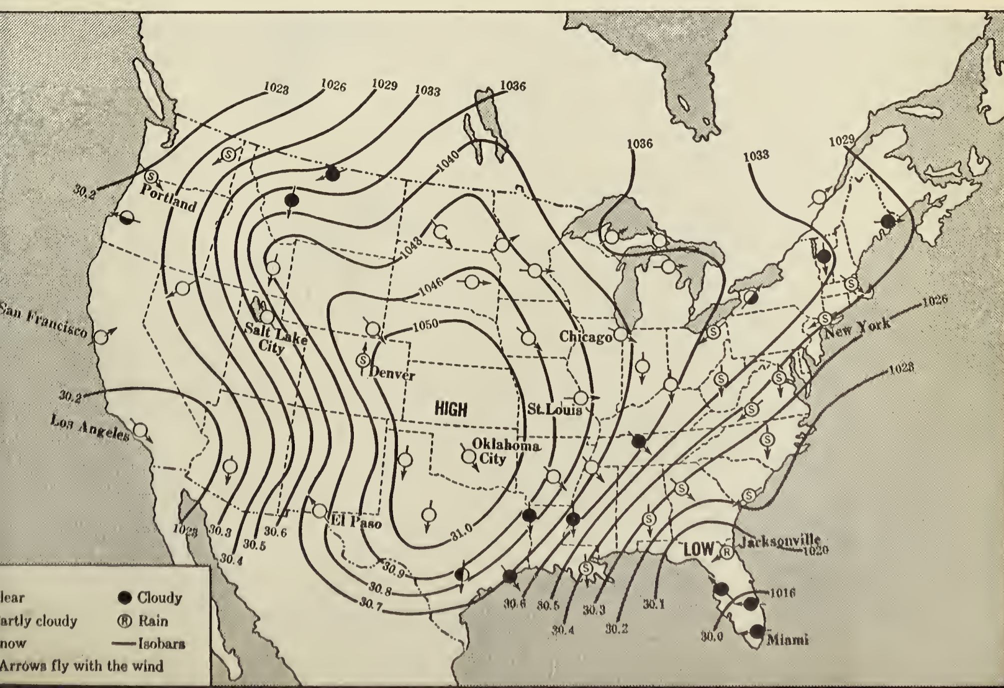
As a cyclone moves over any given region, the direction of the wind in that region gradually changes. With the weather map before him the weatherman knows about how the wind will probably change. From other information he knows whether the change is likely to bring warmth or cold, rain or snow. He also knows whether the winds are likely to increase or decrease in velocity.

On the map pictured above, the city of Chicago was in the area of lowest air pressure at the time the map was drawn. The pressure was only 29.4 inches (996 millibars). In New York, which is located near the outer limits of the area of this particular cyclone, the air pressure was close to 30.1 inches (1020 millibars). This difference in pressure of 0.7 inch between the air around the edge and that at the center caused the wind to blow toward the center of the cyclone. This movement is illustrated by the arrows.

Do you see how it is possible, from the information on a weather map, to predict the weather? All cyclones are much like the one you have just studied. They are huge masses of air gently whirling in a direction opposite to the direction of the hands of a clock (*counterclockwise*), and moving toward a center of low pressure. When the air reaches the center of low pressure, it rises and spreads outward like a mushroom. At the same time the whole mass of air is shifting along with the prevailing westerlies from west to east at the rate of about five hundred miles in twenty-four hours.

The Anticyclone. *Air whirling about a center of high pressure is known as an anticyclone.* "Anti" means "opposite," and in a sense an anticyclone is the opposite of a cyclone. The air pressure in the center of the anticyclone shown in the simplified weather map below is 31.0 inches. Since the pressure is less than this at positions away

This weather map shows the air pressure, wind, and moisture conditions in an anticyclone

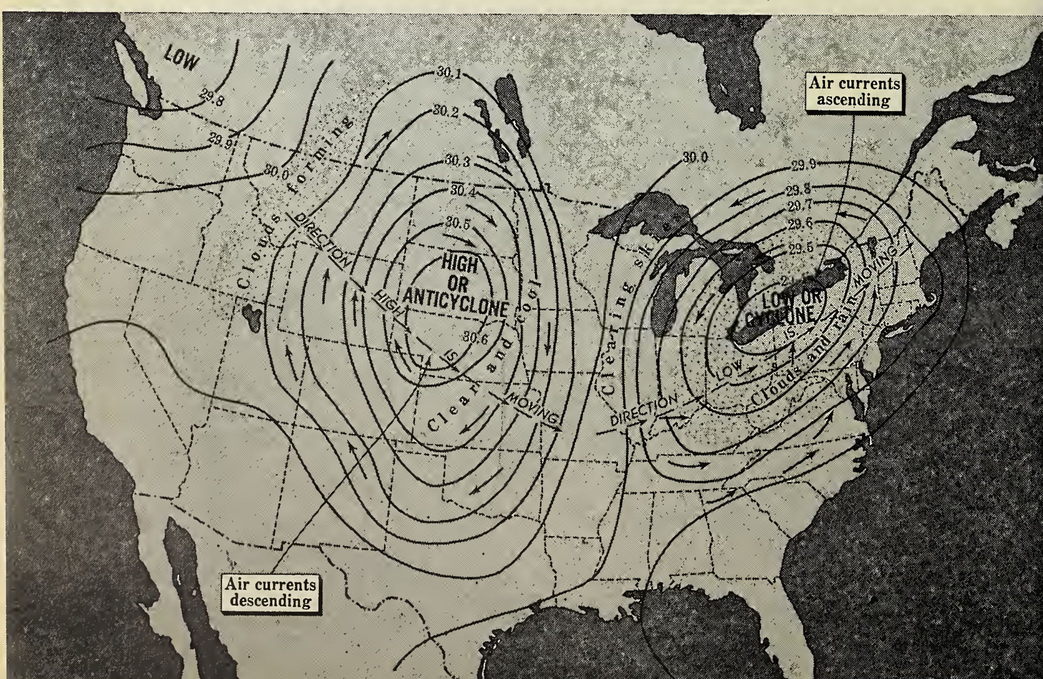


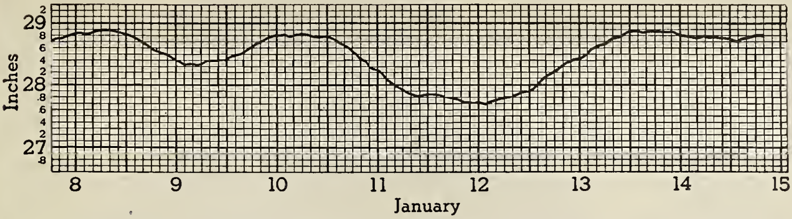
from the center, the winds flow outward. The arrows in the anticyclone show the direction of the wind currents about a region of high pressure. Notice that *the winds whirl outward and in a clockwise direction—just the opposite of air movements in a cyclone.*

Exercise. How to determine the conditions in an anticyclone: Study the weather map on page 141. What is the air pressure over Oklahoma? over Florida? over California? What is the direction of the wind at El Paso? at Denver? at Chicago? What is the general direction of the wind with reference to the center of this anticyclone? Is it generally clear or cloudy within a high-pressure area?

Anticyclones, like cyclones, move across North America from west to east. Like cyclones, they are carried along by the westerly winds, as shown in the map below. For simplicity an anticyclone (high-pressure area) is labeled

Cyclones and anticyclones are carried across the country in a steady stream by the prevailing westerly winds





This graph shows the air-pressure conditions at Huron, South Dakota, over the period of a week

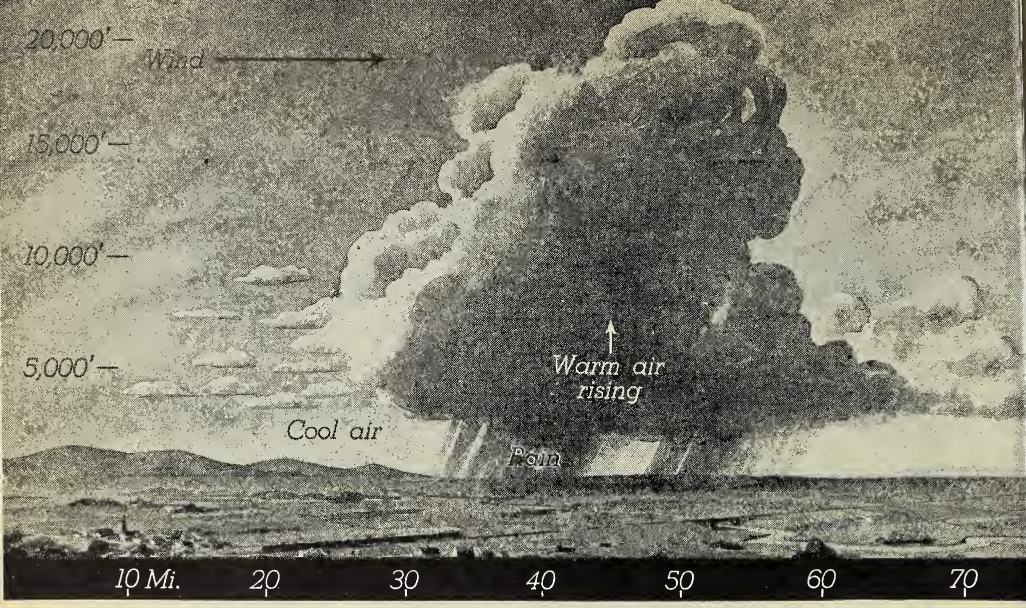
"high" on the weather maps, and a cyclone (low-pressure area) is labeled "low."

Above is a graph which shows the changes in barometer readings at a South Dakota Weather Bureau station. Notice the parade of lows and highs. How many low-pressure and high-pressure areas can you find in this graph? Since the weatherman knows, from careful observation, the conditions that generally prevail within these whirling masses of air, he can predict with considerable accuracy the kind of weather that they will bring.

THUNDERSTORMS AND TORNADOES

Local Storms. Within cyclones local storms of more or less severity may develop. *The thunderstorm is a familiar type of local storm.* It is common in the open prairie and also in the mountains. Thunderstorms are much more frequent in summer than in winter. Passengers in airplanes flying high over the Western Plains frequently see two or more thunderstorms beneath them at the same time. Storms of this sort break on high mountain peaks almost every summer day.

Inside a thunderstorm there is a strong upward current of air. The heated air from the surface of the earth is



This is what goes on inside a thunderstorm

carried to high altitudes, and as it rises it is cooled. Cooling causes some of the water vapor carried by the air to condense, and the first condensation forms great white banks of cumulus clouds. As the clouds get denser, streaks of lightning appear and rain begins to fall. Such cloud banks may rise in the air as high as three or four miles. Within the storm the winds may be blowing furiously. The storm as a whole is generally moving along toward the east. Above is a diagram of a thunderstorm.

Exploring a Thunderstorm. An interesting description of thunderstorms is given by a reckless aviator who deliberately drove his plane into one of them. While within it he lost control of his plane but he did not crash to the ground. The winds carried him upward with great speed for some thousands of feet. After a time, however, he managed to regain control. He escaped from the dangerous adventure without damage to his plane or himself. The experience of

this aviator demonstrated the terrible strength of the air that swirls in the heart of a thunderstorm.

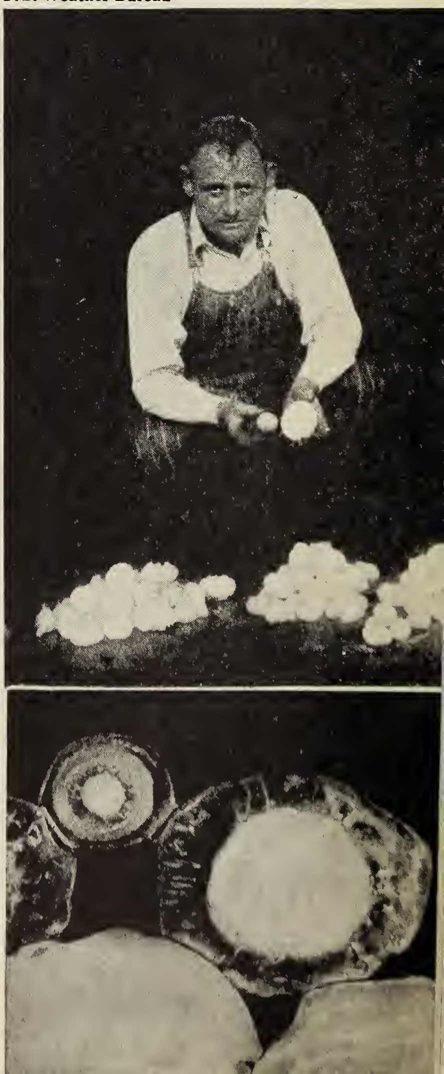
How Hail Is Formed. Heavy rainfall may come from a thunderstorm, but the fall usually lasts only a short time. Sometimes the precipitation is in the form of hail. Under certain conditions hailstones as large as tennis balls are formed. Look at the hailstones shown on this page below.

Though these hailstones fell in summer, they were made in clouds which were high enough above the earth to be very cold. Precipitation may begin to drop from such clouds as snow. As the snow falls, it meets the warm rising air and then melts. The rising air currents—which, as we have seen, are strong enough to raise an airplane—are also strong enough to lift the water that forms from the snowflakes. Back in the region of cold this water changes to the tiny balls of ice which are known as hailstones.

Then, like the snowflakes before them, the little hailstones begin falling, only to be caught in the upward air currents and carried again into the region of cold. As they move through the clouds, more water forms on the surface of each tiny ball. As this water freezes, the

This man is holding an egg in his right hand and a hailstone in his left hand. Hailstones when cut in two (below) are seen to be made of several distinct layers

U.S. Weather Bureau



hailstones get larger. They may fall and be carried back several times. Each trip upward adds more ice to their surfaces, until finally they are so heavy that they fall to the earth. Hailstones, as shown on page 145, may contain several distinct layers of frozen water. Do you see why?

Lightning. Lightning is an electrical explosion which may free as much as fifty million volts of electricity. Thunderstorms become charged with electricity in a way that no one yet fully understands. Lightning may flash between two electrically charged clouds or between a cloud and the surface of the earth. When objects which are poor conductors of electricity stand in the path of a flash of lightning, they may be severely burned.

If you observe a few simple precautions, you need never be afraid of lightning.

1. The bright straight flashes are the ones that "strike." Never stay outdoors when such lightning is flashing.

2. When heavy dark clouds approach from west or south, get under cover. Such clouds may bring dangerous lightning.

3. Do not stand under a tree to keep dry in a thunderstorm because you are then in the possible direct line of discharge of a bolt of lightning. More people are killed by lightning in this way than in any other.

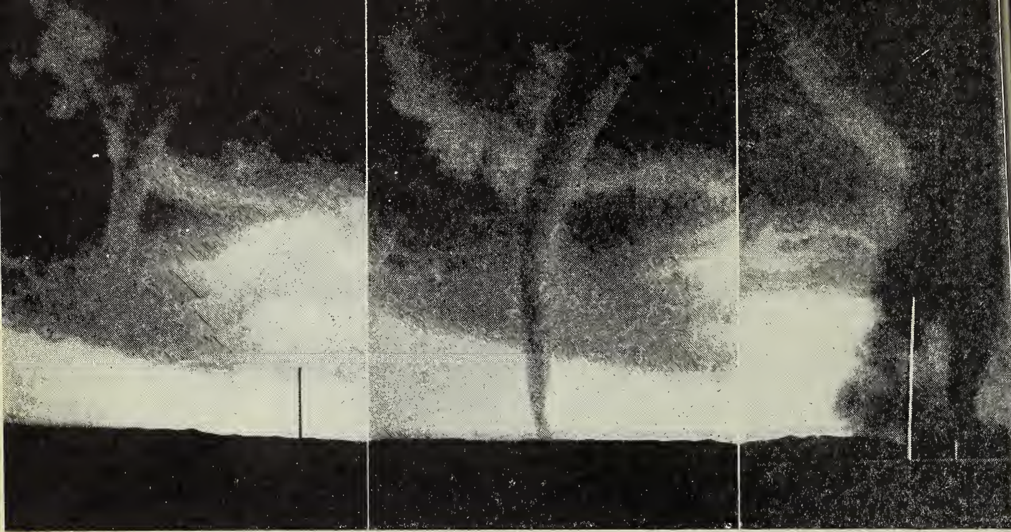
4. During a thunderstorm do not stand in a doorway of a barn or at an open window near a chimney. Lightning frequently follows drafts.

5. Stay away from wire fences.

We might add that after you have taken these precautions, there is no need to worry. Being in your house during a thunderstorm is not nearly so dangerous as crossing an automobile highway on a fine day.

Dr. K. Winfield Ney

The skyscrapers of New York are fine targets for lightning



© Mrs. Roy Homer, Gothenburg, Nebraska

The tornado approaches as a funnel-shaped cloud which strikes the earth's surface in a narrow belt with terrific viole

Thunder. When electricity is discharged as lightning, it intensely heats the air through which it passes. It is this white-hot streak of air that you see as lightning. As the hot air rapidly expands, it violently disturbs the cooler air around it. The noise produced by this disturbance is thunder.

The Rainbow. Who has not been thrilled by the sight of a rainbow? It is one of the most beautiful effects produced by the moisture in the air. The colors in the rainbow are the results of raindrops breaking up the white light of the sun. Have you ever noticed a rainbow in the mist around the bottom of a waterfall or fountain? These little rainbows and the mighty rainbows in the sky are formed in the same way,—by the sun shining on tiny drops of water.

The next time you see a rainbow in a fountain observe that your back is toward the sun. Walk round the fountain until you are facing the sun and observe that the rainbow disappears. The next time you see a rainbow in the sky

observe that the sun is at your back. In order to see a rainbow the observer must always be between the sun and the moisture which breaks up the light of the sun. If a rain cloud is between you and the sun, you will not see a rainbow. That is why rainbows do not appear with every rain and why their beauty is sufficiently rare to be appreciated.

Tornadoes. The tornado, or "twister," is the most violent type of storm that occurs frequently in this country. It is like a thunderstorm, only very much more destructive. These storms are likely to develop locally when a very cold air current meets a very warm current. When this happens, the air may be thrown into a whirl of exceptional violence.

The spinning air of a tornado always turns in a counterclockwise direction in the Northern Hemisphere. Its forward motion (always toward the east) may be as fast as fifty miles per hour. The path of the storm is very narrow, usually not more than a few hundred feet wide, as you can see in the series of photographs on the opposite page.

The air is turning so fast that it is thrown away from the center of the whirl, producing a region of extremely low pressure at the center. When the center of a tornado passes over a house, the air pressure on the outside of the house may be lowered so much and so quickly that the pressure of the air inside the house forces the walls outward. The walls of a room may thus be completely destroyed without any disturbance at all of the table lamp, the telephone stand, or any other object in the room.

Some very peculiar things happen during tornadoes.

This chicken came through a tornado undressed but otherwise unharmed

Fremont W. Wood

This boy is pumping air from the bell jar to see what effect reduced air pressure will have on the cork in the bottle

Feathers have been plucked from chickens by such storms. As the center of low pressure passes over a chicken, the air in its quills expands and the feathers pop out.

If the air pressure on the outside of a bottle is reduced sufficiently, the cork may be forced out of the bottle by the pressure inside the bottle. Corks may thus be blown from bottles as a tornado passes over them.

Exercise. How to show what the reduction of air pressure does to a corked bottle. Fit a cork not too tightly into a bottle and place it under a bell jar, as shown on the opposite page. Pump out some of the air from under the jar. What happens? Why?

Animals may be lifted from the ground by a tornado and carried for long distances. Strange as it may seem, straws carried by the wind may be driven into boards and trees. Look at the illustration below. After one tornado a pine stick was found driven entirely through a poplar tree which was eighteen inches in diameter. In another case a pine board one inch thick and five inches wide was driven through a second board which was two inches thick.

Driving straws into wood is one of the freakiest pranks of tornadoes

Seagoing Tornadoes. Storms similar to tornadoes sometimes form over the sea. Such a storm over the sea is called a *waterspout*. One of these is illustrated on page 152. It was formed when a rapidly whirling column of air sucked water up from the ocean. If

a waterspout moves over the land, the land may be drenched with salt water. Have you ever heard of a rain of fishes? Such happenings are quite unusual, but they have actually occurred. Fish swimming near the surface of a lake or the ocean may be lifted with some of the water by rapidly whirling air, and carried to the land.

HURRICANES

Storms Compared. Another type of destructive storm is the tropical hurricane. These storms take form, as a rule, over the islands of the West Indies. *Hurricanes are usually about halfway in severity between bad thunderstorms and tornadoes.* All three are special types of cyclones. Though ordinary cyclones are not really storms at all, they are masses of air circling in a counterclockwise direction about a region of low pressure—and so are thunderstorms, tornadoes, and hurricanes.

Ordinary cyclones cover very large areas, and their winds are not generally destructive. Thunderstorms cover small areas and in many cases are somewhat destructive. Tornadoes cover small areas, too, but their winds are always terribly destructive. Hurricanes cover wide areas, and though they may be very destructive, they are not generally as severe as tornadoes.

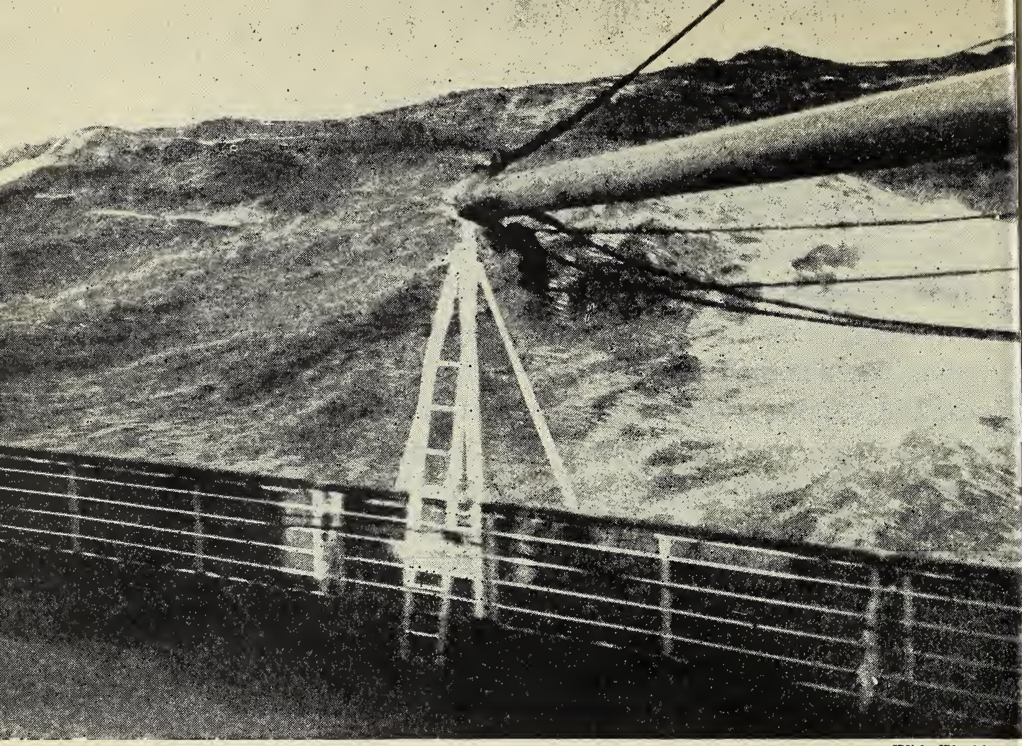
Waterspouts are tornadoes that draw up water from the sea

U. S. Weather Bureau

How Hurricanes Travel. Hurricanes are often carried by the force of the trade winds westward from their place of origin in the West Indies. They may enter the region of the Gulf of Mexico and then swing northward into the westerly-wind belt. One of the most destructive hurricanes ever experienced in the United States was carried westward from the West Indies as far as Galveston, Texas. It struck that city in September, 1900, with terrific force, and killed more than five thousand people. From there the hurricane passed northward and eastward to the Great Lakes, and from there on out to sea over the mouth of the St. Lawrence River. This particular storm was about six hundred miles in diameter. Within the storm the air was moving in a great whirl with force enough to uproot trees and tear down buildings.

At times these tropical storms strike with great force on the coast of the south Atlantic and then move northward, destroying property along the way. Generally, however,

Hurricanes do great damage on the islands of the West Indies



Wide World

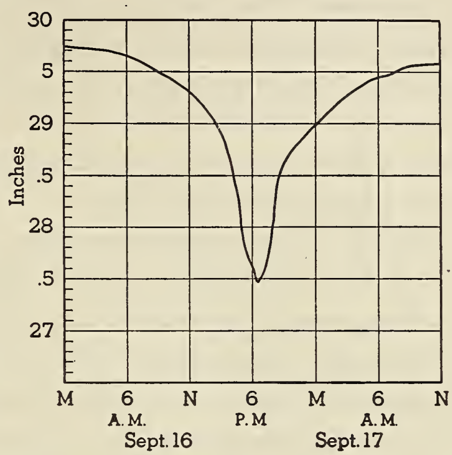
Hurricanes raise monster waves at sea

they spend their fury over the sea before they reach the mainland of North America. On page 153 is a photograph taken on one of the islands of the West Indies after a hurricane had passed.

Many hurricanes move northward over the ocean, and in these cases their damage is only to the ships which are unfortunate enough to lie in their paths. Above is a scene from the deck of a liner in a heavy storm. Notice that the ocean wave is higher than the deck of the ship. The Weather Bureau charts the paths of hurricanes and by means of the radio warns ships to keep out of their way.

The Treachery of Hurricanes. There is one feature about a hurricane which makes it particularly treacherous. Within its center of low pressure there is a region of calm. The air is rising here, but to an observer its motion is not noticeable.

As the hurricane moves toward the observer its coming is announced by strong winds. As the center passes over him, the wind may cease and it may seem as though the storm were over. As the center passes on, however, the region may again be struck by violent winds. *The location over which the center passes may, therefore, suffer not one, but two, violent storms.*



This barograph record tells the story of a hurricane

In 1928 the center of a hurricane passed directly over Miami, Florida. With the approach of the storm there was the usual terrific wind, and considerable damage was done. When the center of the storm arrived over the city, the wind stopped blowing. People, mistaking "the eye of the storm" for the end, came out of their homes to view the damage. After about two hours the destructive winds returned. This time the people were caught off their guard. The loss of life from the second half of the storm was greater than that from the first half.

While the center of this storm was over the city the barometer registered 27.50 inches. This is the lowest sea-level reading of air pressure ever recorded in the United States. Notice in the barograph reading illustrated above that the pressure went down suddenly as the storm approached the city, and then rose again as the center of the hurricane passed.

The New England Hurricane of 1938. The people of the Gulf and lower Atlantic coasts are no longer terrified by hurricanes. They have learned how to build houses and public buildings which will stand against these tropical storms. They know that they will have plenty of warning from the Weather Bureau before the storms arrive, and that with reasonable precautions born of experience they can weather them in safety.

When a freak hurricane tore a wide path across New England in September, 1938, neither the people nor their buildings were prepared for it. Destructive hurricanes are practically unknown so far north. Bostonians heard over their radios that a hurricane was approaching Florida, but it never occurred to anyone that the storm might veer to the north.

That, however, is exactly what it did. It turned away from Florida, entered a trough between two high-pressure areas over the Atlantic Ocean, and headed straight for Long Island. Even then people expected it to turn and die at sea, as so many other hurricanes have done. They were not alarmed. They were utterly unprepared when on September 21 it began its destructive sweep through New England, its air currents whirling at the tremendous speed of seventy-five to a hundred miles per hour.

Passing over Long Island and the coasts of Rhode Island and Connecticut, the wind dragged countless tons of ocean water over the land. Whole communities of seashore homes were washed away. People drowned in the streets of Providence. Tearing through Massachusetts, the wind leveled whole groves of evergreen trees in many places. Sturdy old elms which had battled gales for three hundred years were snapped off like matchsticks or laid low with their roots in the air.

The storm howled fiercely far into the night over nearly the whole length and breadth of southern New England. Gradually blowing itself out as it passed northward toward Canada, it left behind it over six hundred dead and some five hundred million dollars' worth of property damage (see view below).

Storms similar to hurricanes occur in other parts of the world. The typhoons of the Indian and Pacific Oceans are similar in origin to the hurricanes of the Atlantic, and they are equally destructive.

Where Storms Are Born. The circulation of the air and the storms that move over North America really have their origin in the sun. It is heat from the rays of the sun which causes differences in air pressure, which in turn cause the winds to blow. These storms are strong reminders that

The great hurricane of 1938 caught New England completely off guard

Acme

energy from the sun works powerful changes on the surface of the earth.

Europe, Asia, southern Australia, and the southern tips of South America and Africa have storms which are similar to those of North America. In none of these places, however, are the storms exactly the same as ours, for their character is influenced by mountain ranges, nearness to the ocean, inland lakes, and other things. In general, however, storms of similar nature develop in the belts where air currents are flowing between the warm region over the equator and the cold regions around the poles. These currents are driven by forces which have their origin in solar radiation, and they are influenced by the rotating and revolving earth over which they flow. They are among the most common and also the most exciting changes in this changing world.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. The westerly winds are so called because they blow toward the west.

2. The average cyclone does much damage to life and property.

3. The air in cyclones moves clockwise from a central area of high pressure to an outer area of low pressure.

4. The words "high" and "low" on weather maps refer to the elevation of the land.

5. Isobars are dotted lines on a weather map which are drawn through places of equal temperature.

6. Variable winds are winds that blow in all directions because they are outside the belt of the prevailing westerlies.

7. Anticyclones are so called because they move from east to west rather than from west to east, as in the case of cyclones.

8. The air in anticyclones moves counterclockwise from an outer area of high pressure to a central area of low pressure.

9. Anticyclones bring thaws in winter and thunderstorms in summer.

10. Hailstones, when cut in half, show a grain like that of the ice in a refrigerator.

11. Rainbows never appear when the sun is shining.

12. A tornado is a funnel-shaped cloud which moves slowly with the large end of the funnel forward.

13. Waterspouts are hurricanes that form over water.

14. Hurricanes are similar to tornadoes except that they do not last so long and do not cover so wide an area.

Questions for Discussion

1. When do winds blow with greater force—at the time of a small difference in air pressure or at the time of a great difference in air pressure? Which of the maps in this chapter best illustrate these conditions?

2. Can you discover any reasons why tornadoes are fairly common in the central and southern parts of the United States but almost entirely unknown in New England and California? You may get some help in answering this question from either Van Cleef or Brooks, whose books are listed on page 135.

3. Why are hurricanes usually formed in the region of the tropics? The books mentioned in Question 2 will also help you here.

4. Very often in sea stories you read of the fear and worry that come with a falling barometer. What is meant by a *falling barometer* or a *falling glass*? Why should this cause anxiety?

Things to Do

1. Make a collection of newspaper clippings about the weather. Cut out everything you can find on this subject for two weeks or more. You may want to arrange a bulletin-board exhibit of these clippings if they are sufficiently interesting.

2. Have you ever been in a tornado or a hurricane? Have you ever seen a region through which one has passed, a few hours afterward? If so, write an account of what these severe storms are like.

3. Read the United States weather maps every day for a period of two weeks. Try to learn how the weatherman uses the information given on a weather map in predicting the weather. If you do not receive these maps at your school, ask your teacher to write to the nearest Weather Bureau station and ask for them. A small payment will probably be required.

4. Make a special collection of pictures and stories concerning tornadoes and hurricanes. See if you can find any examples of freak damage done by these storms.

CHAPTER SEVEN

What Is Climate?

THE EFFECTS OF THE EARTH'S MOTIONS

Weather and Climate. When you say, "What lovely weather we are having today!" you speak of a condition that ordinarily does not last very long. Yesterday it may have been dark and rainy. Tomorrow it may be cold and windy. Today it is just right; so you say, "What lovely weather!" Weather, in other words, is the *present* condition of the air with reference to heat, cold, wind, rain, and storms.

When you go to southern California and say, "What lovely climate!" you speak of conditions which are more lasting than the weather of any particular day. You say, "What lovely climate!" because yesterday the weather was to your taste and because you expect it to be the same tomorrow.

Climate, however, does not mean unchanging weather. A dry, sunny climate like that of southern California may have periods of rainy weather. A foggy climate like that of London may have periods of dry, sunny weather. A "sunny" climate merely means that the weather is *generally* clear and free from storms. A "foggy" climate means that the weather is *generally* cloudy and damp. *Climate, in other words, is the average weather.*

In the first three chapters of this unit we studied the different conditions which account for the different kinds of weather. We said nothing about the *different combinations of weather conditions* which account for the different

climates of the world. Why does Greenland have a cold climate and Java a hot climate? Why does the Sahara have a dry climate and the Congo a wet climate?

To answer such questions as these we must look beyond the weather. We must even look beyond the air. Much of the explanation of different climates lies in the way the earth travels round the sun.

The Tilt of the Earth's Axis. In Unit One you learned that the earth is forever spinning like a top on an axis which passes through the poles. You learned that while the earth is spinning it is also forever moving in a nearly circular path, or orbit, round the sun. The drawing on the opposite page will refresh your mind about these two important motions of the earth.

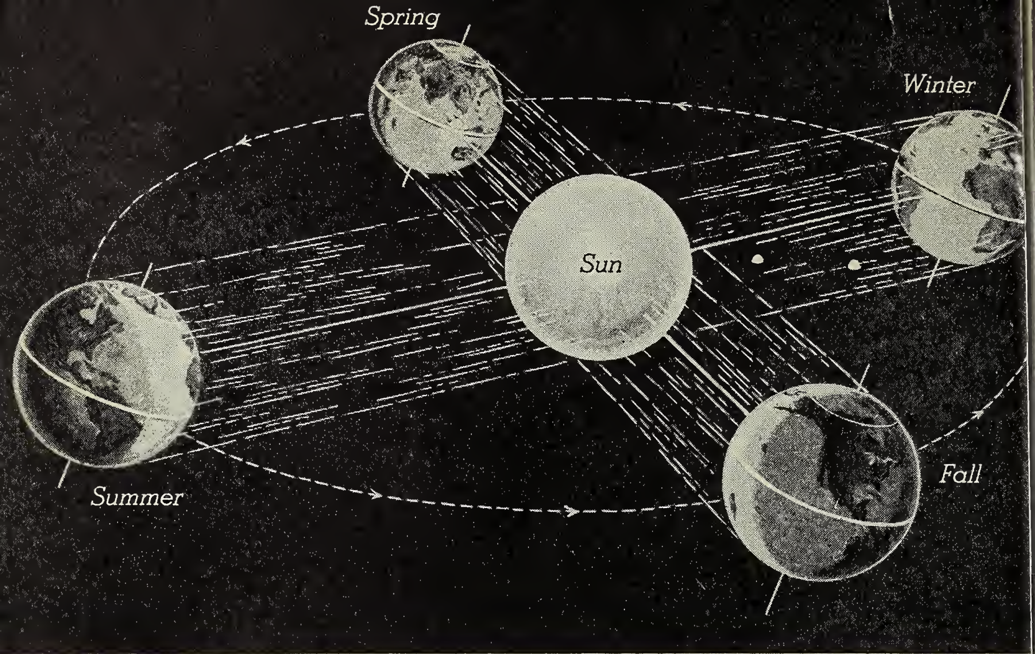
Imagine that the earth is a top spinning on a great invisible floor in the sky. The floor is flat and the earth never jumps off it. Imagine that the sun is in the middle of the floor, and that the orbit of the earth is a chalk line drawn on the floor round the sun. This invisible floor

There are different ways of enjoying different climates

The earth has two important motions

represents what astronomers call *the plane of the earth's orbit*. "Plane" means "flat," and "plane of the earth's orbit" merely means that the earth travels round the sun like a top traveling in a circle on a floor.

Next imagine that the earth is spinning on this floor like a poorly spun top. It is not spinning with its axis straight up and down (perpendicularly) but on a slant. This slant, or tilt, of the earth's axis is shown in the diagram on page 164. Notice that no matter where the earth happens to be in its orbit, its axis always slants away



This diagram shows what causes the different seasons

from the perpendicular. Astronomers have measured the amount of tilt and have found it to be $23\frac{1}{2}$ degrees. This angle of tilt is always the same throughout the earth's journey round the sun.

What Causes the Seasons. As the earth revolves in its orbit with its axis pointing toward the North Star and tilted in the way we have just described, the rays of the sun naturally fall upon it differently at different times. Notice in the diagram above that when the earth is in the position marked "winter," the northern end of its axis is tilted *away* from the sun. More sunlight falls on the part of the earth which is south of the equator than on the part which is north of the equator. When the earth is in this position, the Northern Hemisphere has winter and the Southern Hemisphere has summer.

Notice that when the earth has moved round the sun to the position marked "summer" in the diagram, the north-

ern end of its axis is tilted *toward* the sun. In this position the part of the globe which lies north of the equator receives more of the rays of the sun than the part which lies south. Accordingly it is summer in the Northern Hemisphere and winter in the Southern Hemisphere.

Notice finally that when the earth is halfway between the positions marked "summer" and "winter," the rays of the sun strike the Northern and Southern Hemispheres equally. This condition happens twice each year, when the earth moves into the positions marked "spring" and "fall."

Many differences in climate, which we shall study later in this chapter, are based on these different ways in which the rays of the sun strike the earth.

Differences in Length of Day and Night. We have all noticed that the hours of daylight and darkness vary with the seasons. In summer our days in the Northern Hemisphere are long and our nights are short. In winter our days are short and our nights are long. These differences, like the differences in the seasons, are due to the different ways in which the rays of the sun strike the earth as the earth goes around in its orbit.

On or about June 21 the earth is in the position marked "summer" in the diagram on page 164. The northern end of its axis is tilted toward the sun. The drawing on page 167 shows in more detail how the surface of the earth is lighted on that date.

Notice that the vertical rays of the sun strike the earth well north of the equator. Notice that still farther north the rays strike the earth on more and more of a slant. Notice that the rays extend beyond the north pole, and that all the region around the pole is in sunlight. The region around the north pole, indeed, is exposed to the

sun throughout the entire twenty-four hours of the earth's rotation on its axis. It is truly the Land of the Midnight Sun at this time of the year. At the same time all the region around the south pole is in darkness. The sun's rays do not extend into it at all.

It is easy to see that *more than half of the Northern Hemisphere and less than half of the Southern Hemisphere* are in daylight when the axis of the earth is pointing directly toward the sun. In other words, while the earth is turning once on its axis, every spot in the Northern Hemisphere is lighted by the sun *more* than half the time and unlighted less than half the time. In the Southern Hemisphere, on the other hand, every spot is lighted *less* than half the time and unlighted *more* than half the time. If you could travel northward from the equator in June, you would find the time of sunrise earlier and earlier and the time of sunset later and later. Finally you would come to a region where the sun is above the horizon through all the twenty-four hours.

On or about December 22 the earth is in the position marked "winter" in the diagram on page 164. The northern end of its axis is tilted away from the sun. *On December 22, therefore, the Southern Hemisphere is lighted exactly as the Northern Hemisphere is lighted on June 21.* In December the periods of daylight and darkness in southern Argentina, for example, are the same as they are in the United States in June. In December it is summer in Argentina while it is winter in the United States. (Similarly, in June it is winter in Argentina and summer in the United States.) Through the winter months of the Northern Hemisphere the region around the south pole is the Land of the Midnight Sun and the region around the north pole is the Land of Midday Darkness.

How the earth is lighted on the first day of summer

Consider next what happens when the earth is in the position marked "fall" and "spring" in the diagram on page 164. On or about September 23 the earth is in the position marked "fall." The vertical rays of the sun are directly over the equator. The slanting rays fall as much upon one pole as upon the other. *As a result, all places in the world have twelve hours of daylight and twelve hours of darkness on this date.* The same condition occurs again six months later, on or about March 21, as shown at "spring" in the diagram. These two days are called the *autumn* (or *autumnal*) *equinox* and the *spring* (or *vernal*) *equinox.* "Equinox" means "equal night" and refers to the fact that at these times day and night are of equal length.

Do you see that as the earth travels round the sun the seasons change, and with them the length of day and night?

Exercise. How to find the difference in time of sunrise and sunset at places to the south and to the north of you: Use an almanac for information and show in a table the time of sunrise and sunset for the following places (*do not write in the book*):

	June 21		December 22	
	Sunrise	Sunset	Sunrise	Sunset
Where you live . .	---?---	---?---	---?---	---?---
Miami	---?---	---?---	---?---	---?---
New Orleans . . .	---?---	---?---	---?---	---?---
Montreal	---?---	---?---	---?---	---?---
Nome, Alaska . .	---?---	---?---	---?---	---?---

Are the days longer or shorter in summer in the cities to the north of you? Are they longer or shorter in winter in the cities to the south of you? Why?

Why Summer Is Warmer than Winter. Along with seasonal changes in the length of day and night come familiar changes in temperature. We all know that as the days shorten it gets colder, and that as they lengthen it gets warmer. Do you know, however, why this is so? Let us see.

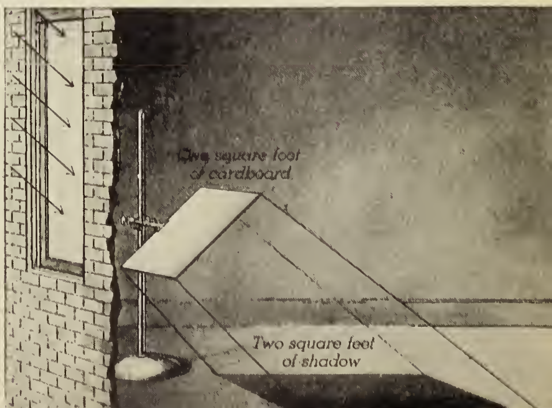
The earth is warmed by radiant energy from the sun. The sun's rays are not heat, because out in space where these rays are most intense, the cold is extreme. *The sun's rays are changed into heat when they strike objects on the surface of the earth.* The fact that solar radiation is changed into heat may be illustrated with the help of a large reading glass.

Exercise. How to prove that the sun's rays may be turned into heat: Hold a reading glass so that the sun's rays pass through it and come together in a point, or "focus," on your hand. What do you feel? Focus the rays on a match. What happens? How can you explain these results?

The amount of energy that comes from the sun may be measured. In the drawing below is shown a cardboard surface of one square foot held in such a way that the rays from the sun fall upon it vertically. If the cardboard were not there, the rays would strike the floor at a slant. The shadow under the cardboard shows where these slanting rays would strike. *Notice that they would cover not one, but two, square feet of the floor.*

On the floor, then, the energy of the beam of sunlight would be distributed

A beam of light covers more area when its rays strike on a slant than when they strike vertically

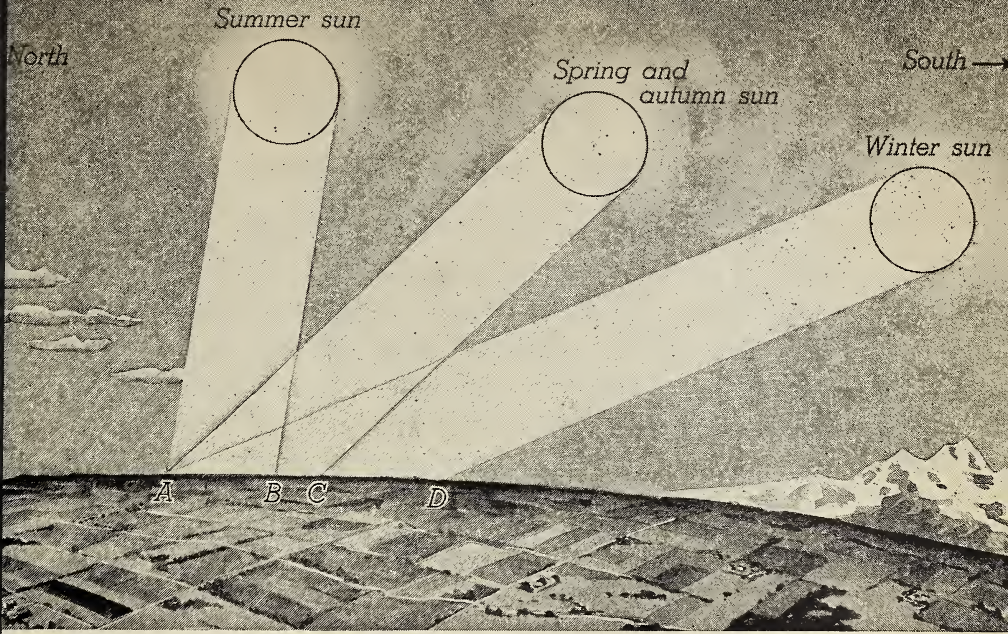


over an area that is twice the area of the cardboard. It follows, does it not, that the amount of energy which the beam brings to the cardboard is twice as great as the amount of energy which the same beam would bring to an area on the floor the size of the cardboard. In other words, *the slanting rays on the floor would be only one half as intense as the vertical rays on the cardboard.*

Now let us apply what we have learned from this observation to general conditions upon the earth. The intensity of the heat from the sun at positions north or south of the equator is always less than at the equator. It is true that the sun is directly above the equator only two days of the year: March 21 and September 23. If you will consider the entire earth, however, you will see that the sun is more nearly overhead at the equator *for a greater number of days* during the year than at any other point on the surface of the earth. Do you see, then, why the equator is generally the warmest region on earth?

At your position in North America the sun is never directly overhead. Study the illustration on the opposite page. This represents a section of the earth at about the latitude of Chicago. Even at noon in the summer, when the sun is highest in the sky, it is always a little south of directly overhead. For this reason a beam of sunlight one foot square spreads over an area that is more than one foot square. (Refer to the drawing on page 169 again if you do not see why this is so.)

In the summer, with the sun almost directly overhead, a beam of sunlight may cover the area *A–B*. As the earth moves in its orbit the rays of the sun strike it on more and more of a slant. A beam of the same width, therefore, covers a larger and larger area. Contrast *A–B* with *A–C* and with *A–D*. Do you see why in our latitudes summer is



e different temperatures of the different seasons are due to the different angles at which the rays of the sun strike the surface of the earth

generally warmer than spring and autumn? Do you see why spring and autumn in their turn are generally warmer than winter?

In your study of day and night you learned that the days are longest in the Northern Hemisphere when the vertical rays are north of the equator. Now you have learned that the heat from the sun is most intense when the sun is most nearly overhead; that is, when the rays strike the earth more nearly at the vertical. These facts explain why our summers are hot and our winters cold.

Near the equator there is comparatively little difference in either the amount or the intensity of sunlight from summer to winter. As one goes farther north or south from the equator, the differences become greater. These differences make the summers in both hemispheres hot and the winters cold. They have a great effect upon life, as we shall see.

THE ZONES OF THE EARTH

How the Earth Would Look to a Martian. Suppose you were a schoolboy on Mars looking at the earth through a powerful telescope. What might you expect to see? Probably the first things to catch your attention would be the white ice caps over the poles. If you observed these caps over a period of several months, you would see that the northern cap appeared larger than the southern cap at one time of the year. Six months later the southern cap would appear larger than the northern cap.

In addition to the polar caps you would notice great land and water areas. As the ice over the north polar region shrank, the land areas below it would take on a greenish tint. The green tint would spread over most of the lands of the Northern Hemisphere. At the same time the white area of the south polar region would extend farther and farther north, as ice spread from the cap over the surrounding ocean.

You would also notice a broad band of brilliant green extending around the earth halfway between the poles. This band would always be green; unlike the colors north and south of it, its color would not change from time to time. Perhaps if your telescope were good enough, you would see on the land areas two narrow brown belts of barren desert on either side of the green equatorial, or central, belt.

Suppose you sketched a map of the earth as you saw it through your telescope. What would it be like? Whether you chose the hemisphere containing North America and South America or the one containing Europe, Asia, Africa, and Australia, the colors would be the same at the same time of year. There would be blue for the water; a brilliant

green band across the equatorial land areas equal in width to about one fourth the distance between the poles; brown desert areas on each side of this, each equal in width to about one tenth the distance between the poles; strips which are green (if viewed in summer) or brown and white (if viewed in winter) on each side of the desert areas, each almost as wide as the green band at the middle; and a white cap at each pole.

What Causes the Different Zones. As you looked at your finished map, you would see a globe rather definitely divided into bands or zones. As a Martian you could not explain them any better than the people on the earth can explain the appearance of Mars. As a dweller on earth, however, you can easily learn how to explain them.

Most of these color zones, or belts, have definite names which you have probably already learned in your study of geography. Beginning at the north pole, they are called the north frigid, or arctic, zone; the north temperate zone; the torrid, or tropical, zone; the south temperate zone; and the south frigid, or antarctic, zone.

How are the boundaries of these zones determined? First, let us see what the boundaries really are. As the map on page 174 shows, the north frigid zone extends from the north pole to a line $23\frac{1}{2}$ degrees south of the north pole (or $66\frac{1}{2}$ degrees north of the equator). Can you see any connection between this and what you know about the way in which the earth's axis is tilted?

You will remember that the earth's axis is tilted, or inclined, from the perpendicular to the earth's orbit at an angle of $23\frac{1}{2}$ degrees. We have seen that when the earth's position in its orbit is such that the inclination of its axis is toward the sun (on or about June 21), the rays of the

The zones of the earth are determined by the tilt of the earth on its axis

sun pass over the north pole. The entire region between the north pole and a line 23½ degrees south of the north pole is lighted by the sun on this date. This line, or parallel, is called the *arctic circle*, and the region within the arctic circle is called the *north frigid, or arctic, zone.*

The *antarctic circle*, which lies 23½ degrees north of the south pole (or 66½ degrees south of the equator), is defined in the same way. The region south of the antarctic circle is entirely lighted on or about December 22, when the southern end of the globe is inclined toward the sun. This region is called the *south frigid, or antarctic, zone.* Do you see, then, how the tilt of the earth's axis determines the boundaries of the frigid zones?

As you have learned, the vertical rays of the sun continuously shift back and forth from north to south as the earth makes its endless journey round its orbit. Because of the $23\frac{1}{2}$-degree tilt of the axis, the shift takes place between lines, or parallels, which lie $23\frac{1}{2}$ degrees north and south of the equator. These parallels mark the boundaries of the *torrid, or tropical, zone.* The northern boundary of the torrid zone is called the tropic of Cancer; the southern boundary is called the tropic of Capricorn.

The territory between the tropic of Cancer and the arctic circle is called the *north temperate zone,* and that between the tropic of Capricorn and the antarctic circle is called the *south temperate zone.* The north temperate zone, therefore, lies between $23\frac{1}{2}$ degrees and $66\frac{1}{2}$ degrees north latitude. The south temperate zone lies between $23\frac{1}{2}$ degrees and $66\frac{1}{2}$ degrees south latitude. Each of the temperate zones, accordingly, is 43 degrees wide.

It is important to know that the boundaries of these zones were not determined by the whims of geographers. They are determined by the tilt of the earth on its axis. The different climates of the earth do not correspond exactly to the different zones because local conditions make their boundaries irregular. Climates, however, are very much affected by the way in which the sunlight strikes the earth, as we shall see.

THE DIFFERENT CLIMATES OF THE EARTH

The Region of Wet Heat. The hot vertical rays of the sun shift with the seasons, as we have seen, between the tropic of Cancer and the tropic of Capricorn. Heavy rains follow the shifting heat. Together the sun and the rain determine the climate of the broad middle belt of the earth.

Much of Africa, South America, India, the East Indies, and northern Australia are extremely hot and wet during much of the year, particularly those parts which lie on or near the equator. There the sun beats down without mercy day after day and month after month. The air near the surface of the earth is intensely heated; it is continuously rising, cooling, and dropping its moisture. *The result of these conditions is the greatest heat, the heaviest rainfall, and the densest plant growth on earth.*

The climate of the torrid zone, however, is not everywhere the same. Elevation above the sea and distance from the equator determine the degree of heat and moisture. Let us join an imaginary party of explorers as they travel down the Amazon River, and see if we can discover what the climate of the torrid zone really is.

High Elevation in the Tropics. The Amazon flows across South America from west to east, as you can see in the map below. Let us begin our journey at Quito, Ecua-

The Amazon flows across northern South America parallel to the equator

Ewing Galloway

High elevations in the torrid zone have healthful and pleasant climates

dor, high in the Andes Mountains on the equator. We find Quito a pleasant enough place. At night the thermometer may fall as low as 30° F., but at noon it may rise as high as 75° F. This is quite a range of temperature, and we are glad we brought along a few warm clothes.

The natives tell us that the temperature does not change much from month to month; that the average monthly temperature throughout the year stays close to 54° or 55° F. They also tell us that the yearly rainfall is not much greater than that of Boston and less than half as great as that of the lowlands to the east.

Quito is surrounded by such high peaks (some of them more than 20,000 feet above sea level) that it is never without sight of snow. Though the mountains have their

roots in the equator, their heads are high enough in the cool upper air to wear snow caps the year around. Below them the city basks in a sort of everlasting spring, with a healthful and pleasant climate despite its position on the equator. It is typical of other tropical places of high elevation. These places afford happy exceptions to the general unhealthful and unpleasant climate of the torrid zone.

We leave Quito for the climb across the Andes. After several days we arrive on the east slope, where a stream rushes madly down a canyon. We follow this stream, a tributary of the Amazon, until the towering Andes are well behind us. After we have traveled a few hundred miles we come to the main body of the Amazon. We still have more than two thousand miles to travel before we reach the mouth!

Suppose it was Christmas when we set out from Quito. The sun has not been directly over our heads because at this time of year in the tropics its vertical rays strike south of the equator, over the tropic of Capricorn. The sun, however, is only $23\frac{1}{2}$ degrees south from the *zenith*, or highest point in the heavens. The days and nights are about of equal length. Because we shall never be far from the equator throughout our journey we do not expect any seasons such as we know in the United States. We expect the temperature to stay much the same throughout the year.

As we paddle down the river to the east in canoes, we come to Indian villages, some of them a mile above the level of the sea. The people in these villages live on the equator, but because of the high elevation the climate of their country is not unlike that of our summers. We observe that the Indians cultivate the soil and grow crops which consist, among other things, of potatoes, squashes, corn,

sweet potatoes, and tomatoes. They seem fairly healthy and happy.

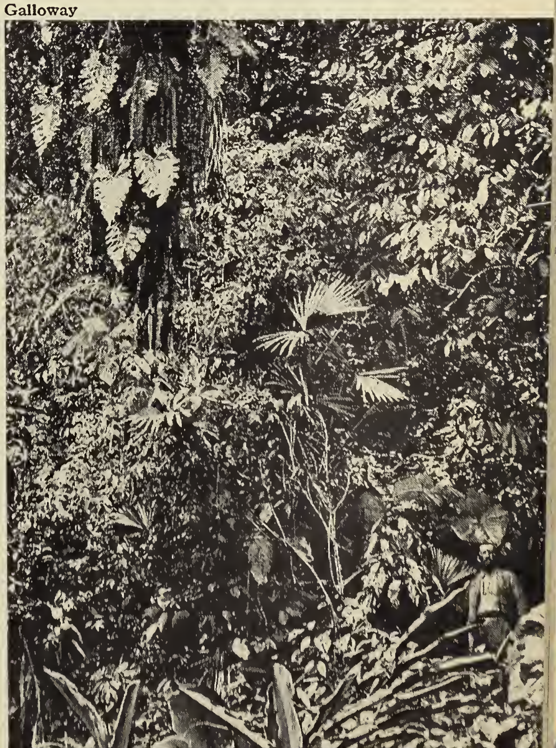
The Jungle. Traveling several hundred miles farther to the east—beyond the high country and down into the lower lands of Brazil—we come to regions abundantly covered with vegetation. We begin to feel the damp, hot air so typical of the lowlands of the equator. Even though it is at present the so-called dry season, we see that the "dry season" is not really very dry. There is as much rain here every month as Chicago gets during its rainiest month. It is dry only in the sense that there is less rain now than at other times.

In these lowlands there are monkeys, snakes, and thousands of different insects. Ants and mosquitoes are everywhere. Though it rains a great deal, the sunlight is intense when the sky is clear. Here grow the rubber trees and the great snakelike vines so common in the tropical jungle. A typical jungle scene is shown at the right.

The Rain Forests. Still farther to the east, where the river is wider and where the current glides slowly across nearly level land, we enter the great stretches of the equatorial rain forests. These forests differ from the jungle in several ways. Their trees are taller, their vegetation denser. It is hotter, damper,

The giant plants of the jungle make a man look small

Galloway



Hamilton Rice Expedition

Rivers are practically the only roads through the thick and gloomy rain forests of the trop

and darker. Sunlight seldom reaches the ground through the thick masses of leaves. Paths are swallowed up by plant growths almost as soon as they are cut. It is an all but impenetrable wilderness. Compare the jungle shown on page 179 with the rain forest shown above.

The journey down the river has been slow. As time passes, the sun moves northward until in March it is directly over our heads. We are now in the midst of the rainy season, when more rain falls each month than falls in Los Angeles in an entire year. The river has swelled to a raging torrent, and travel has become very dangerous. Finally, however, we near the mouth of the river in safety. It is June and the vertical rays of the sun have moved over our heads to the north. They are now nearing the tropic of Cancer, and the rainfall is not so heavy where we are. After

six months of adventure we have completed our difficult journey along the equator from the Pacific to the Atlantic Ocean.

We have passed safely through one of the most unhealthful regions on earth. We have seen a sample of the ten million square miles of equatorial lands which are really not fit for humans to live in. We have seen the natives sitting listlessly by their huts or wearily stalking game with poisoned arrows. Hemmed in their little clearings by the jungles and the forests, tormented by hot rains and poisonous insects, sapped of energy by heat and disease, they live lives only a little richer than those of their animal neighbors. The climate does not give them a chance to grow civilized.

The Ricelands. From the equator to about 10 degrees north and south, the sun and rain and vegetation rather generally suffocate all attempts at civilized life. Away from the equator on either side, however, the rainfall grows less abundant. The tangled jungle and forest growths give way in places to fields of rice. Indeed, some seven hundred million people in tropical lands depend chiefly on rice for their living.

The photograph on pages 182–183 shows a rice field on the island of Java, where tropical civilization has perhaps reached its highest state of development. Rice is both a water-loving and a sun-loving grain, and Java is a perfect home for it. Notice the mountains behind the fields. It is water from the streams which flow off these mountains that the farmer uses to irrigate his land. Notice also the peculiar mudbanks which curve like snakes across the fields. These banks keep the water gently moving over the growing rice.

In Java the temperature averages close to 80° F. the year around. Sunshine and rain are so plentiful that the good farmer can get two or three crops a year. Java is made up chiefly of volcanoes, but so productive are the rice fields at the feet of the volcanoes that they support about thirty-five million people, nearly the population of France.

The Grasslands. Between 10 degrees and 20 degrees north and south of the equator, in the belts of the trade winds, the jungle gives way to land which is covered by scrubby trees and grasses. On many vast grassy plains of Africa and India the sod is too tough for the plow. Water is

Life Magazine

Life on the grasslands is an endless search for good pastures

scarce because these regions are on the outer edge of the shifting belt of heavy tropical rains. They have "dry" seasons which are really dry.

The result is that the inhabitants of these lands are herdsmen. They drive their cattle from place to place in an endless search for good pastures. They do not stop long enough to grow highly civilized.

The Desert Lands. Between about 20 degrees and 30 degrees north and south of the equator, where the torrid zone gives way to the temperate zones, the westward-blowing trade winds give way to belts of calm (the horse latitudes shown on page 101). These belts are too near the equator to receive much moisture from the westerly winds. They are too far from the equator to receive much

moisture from the shifting zone of heavy tropical rains. They are, accordingly, hot and dry except for a few months in winter. It is in these belts that the world's greatest deserts lie.

The photograph below shows an Arab camp on the Sahara Desert. Like most dwellers in other desert regions, the Arab is doomed to a wandering life. He must follow the infrequent showers in search of grass for his little flock. He must battle the wind, the drifting sand, and the intense dry heat of a barren country. It is no wonder that he has grown strong and fearless and self-reliant. The weaklings of the desert have perished long ago.

The Temperate Zones. Beyond the desert regions and midway between the equator and the poles are the lands where the west winds blow. There, in the so-called temperate zones, climate is truly friendly to man. It is neither

Only the strong can wrest a living from the Sahara

Ewing Galloway

too hot nor too cold, too wet nor too dry. Because of this the six hundred million people who live in these zones are the healthiest and most highly civilized people on earth.

In the temperate zones the seasonal changes have a greater influence on life than anywhere else on earth. So many and important are the examples of this influence that we shall devote a large part of the next unit to their study.

The Frigid Zones. Between 75 degrees of latitude and the poles, the ground is frozen throughout the year. Plant life is scarce or entirely absent. People who live in such lands as northern Siberia, Alaska, and Greenland must look rather generally to the seal and the walrus and to fish from the sea for food. They must battle the cold as the people of the equatorial regions must battle the heat.

Some of the lands of the north frigid zone are covered with moss which the reindeer can eat. Such lands are known as *tundra*. The photograph at the left shows a herder of reindeer on the windswept pastures of the tundra. She lives, perhaps, a little more comfortable and civilized life than the Eskimo hunters. On the whole, however, the climate of the frigid zones is not very productive of either comfort or civilization.

This woman is a herder on the arctic tundra

Julien Bryan

Variations in Climatic Belts. The different climatic belts of the earth which we have just described are not sepa-

rated from one another by hard-and-fast lines. Bodies of water, mountain ranges, ocean currents, and other influences make the boundaries very irregular. All the conditions which we have studied in this unit help determine the different climates of the world. In general, however, the climate of any given region depends *chiefly* on the way in which the sun's rays strike it as the earth moves around in its orbit.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. "Climate" is just another name for "weather."

2. The reason that climates are different in different parts of the world is that the angle of tilt of the earth's axis is continuously changing.

3. When it is summer in Chicago it is winter in Tokyo.

4. In winter in the Northern Hemisphere the axis of the earth is tilting toward the sun.

5. If you traveled southward from the north pole in June, you would find the days getting longer and the nights shorter.

6. Summer is warmer than winter because in summer the rays of the sun strike the earth on more of a slant.

7. The torrid, temperate, and frigid zones were invented by geographers to make it easier for them to discuss the different climates of the earth.

8. The climate of the torrid zone is everywhere hot and rainy.

9. The jungles of tropical lands are sometimes known as "rain forests."

10. There is no farming in the tropics because plenty of food grows wild in the jungle.

11. Most of the deserts of the world are within 10 degrees of the equator.

12. All the people of the frigid zones are hunters.

13. The boundaries of the climatic belts of the earth are as definite as the boundaries of states and countries.

Questions for Discussion

1. What differences do you think might exist in the climate of North America if the earth's axis were tilted 60 degrees instead of $23\frac{1}{2}$ degrees?

2. Upon a hillside sloping toward the south you will notice that even in midwinter the sun's rays seem warmer than they do on level ground. Why?

3. Here is a suggestion for a lively class discussion. Have each of the pupils write what he thinks an ideal climate should be like. Then let each read aloud what he has written and allow the rest of the class to criticize it.

Things to Do

1. Make a graph showing the time of sunrise and sunset each morning and night for a month. Use an almanac to find the exact time. Do the days grow longer or shorter? Why?

2. Make a wall chart showing how the tilt of the earth's axis and the revolution of the earth round the sun cause changes in the length of day and night and in the seasons in the latitude of your home.

3. Ontario, Canada, and the Bahama Islands were both settled by Englishmen. Compare the types of civilization

which exist in these two places. Take into consideration education, industriousness, government, and so on. Then compare the climate of the two places. Do you see any relationship between the climate and the type of civilization in each place? Explain any conclusions or comparisons made as a result of this study.

4. Write an advertisement for a company with land to sell in the tropical jungle of South America. Be truthful and base your claims on fact. Write a similar advertisement for a company with land to sell in northern Siberia.

5. A former president of the United States, Theodore Roosevelt, once explored an unknown part of the Amazon Valley. He discovered a new river, which he called the River of Doubt. It was later called Rio Téodoro and is now known as River Roosevelt. See if you can find his book *Through the Brazilian Wilderness* in your library. Read it and report on what he discovered on his trip.

6. Read *Uncle Sam's Attic*, by Mary Lee Davis, or *The Friendly Arctic*, by Stefansson. Note especially the descriptions of the long summer days and the long winter nights, with their effects upon the inhabitants of the Far North.

UNIT THREE

THE CHANGING WORLD OF LIFE

Have you ever seen a tree shed its leaves in summer and then put on new ones in the winter?

Have you ever heard of bluebirds flying north for the winter and south for the summer?

Have you ever been tempted to go bathing in a ski suit and skiing in a bathing suit?

If these questions seem silly, it is only because you know that there is a proper time and a proper place for everything.

Everywhere we go we see living things doing what they do at the proper time and in the proper place.

They are, as scientists say, adapted to their environment.

In a world of changing seasons, weather, and climate, adaptations must also change.

Just as the driver of an automobile changes the speed and direction of his car as traffic and road conditions change, so do adaptations change in a changing world.

The changes and differences in the adaptations of living things are among the most common sights in the world.

Unit Three of this book will try to explain some of the most interesting of these sights.

CHAPTER EIGHT

How Do the Changing Seasons Affect Plants?

ACT I · SPRING

The Drama of the Seasons. The earth is the stage on which a mighty play is acted out each year. Every time the earth goes round the sun the play is repeated. As long as the earth continues to go round the sun, the play will go on. As long as the axis of the earth continues to be tilted as it now is, the play will continue to have four acts. We might call the play "The Drama of the Seasons." Its four acts are Spring, Summer, Autumn, and Winter.

We in North America are especially well located to watch this great performance because we live in a region where the seasons are most clearly set off from one another. We can easily observe what happens during any given season. We can compare this with what happens during each of the other seasons. Whether we live in the north or the south, the west or the east, we may observe the Drama of the Seasons, though in different regions the setting of the stage is different.

We cannot, however, watch everything at once. The Drama of the Seasons is like a circus, with many actors doing different things in different places at the same time. Everything on earth, indeed, takes part in the play. The chief actors, however, are plants and animals. They work together in every act, but their parts are very different. Let us, then, first study the role of plants in this greatest show on earth.

The Play Begins. The sun is the producer of the Drama of the Seasons. Countless changes which take place on the earth from season to season are made possible by the sun. In winter, when the vertical rays are far to the south of the north temperate zone, last year's drama quietly comes to a close. As the vertical rays creep northward with spring the stage is set for another performance.

The water in the soil which in Canada and the northern part of the United States has been tightly frozen for months begins to move again. Streams are flooded with water from melting ice and snow. Signs of spring may be observed in the Southern states soon after the vertical rays begin to move northward. As time passes, these signs may be observed farther and farther toward the north. Warmth and moisture begin to soak into seeds and buds which have been long asleep. The seeds begin to sprout, the buds to swell, the brown earth to brighten into green. The curtain has risen and the play has begun.

Green Plants Need Warmth and Moisture. In watching the springtime changes in the world of plants it is easy to see that warmth and moisture are very important in bringing these changes about. The plants that tint the spring landscape with green will not sprout when the soil is cold or dry. We all know this from observations which we have already made.

A few simple experiments, however, will show you exactly how important moisture and warmth really are in the lives of growing things. You can perform these experiments indoors if it is cold where you live at the time you study this unit. It will take several days to complete them, but they will be interesting to do while you go ahead with your study of this chapter.

H. Armstrong Roberts

With the touch of the sun in spring, life wakens from its winter sleep

Exercises. How to prove that green plants need warmth: Plant four bean seeds in each of two flowerpots which have been filled with good moist soil. Place one pot in a refrigerator and the other in a warm room. Keep the soil in both pots moist and observe them for several days. What happens? What is the effect of warmth and cold on the seeds?

How to prove that green plants need moisture: Plant four bean seeds in a flowerpot which contains some very dry soil. To be sure that the soil is very dry, first place it in a broad shallow pan on a warm radiator and let it stay there overnight. Do not water the pot after you have planted the seeds. Place it in a warm room and observe for several days. What happens? What is the effect of lack of moisture on the seeds?

Green Plants Need Sunlight. The above experiments will show you two of the greatest needs of green plants. Warmth and moisture, however, are not their only needs. Sunlight is equally important, as a few observations and experiments will prove.

Plants grown in dark places are unhealthy. Where the sunlight is regularly brighter on one side of a pot of plants than on the other side, the plants will lean toward the light. They seem to reach for the light, without which they cannot grow strong and healthy (see opposite page).

Have you ever noticed that the leaves of green plants tend to spread out so that all the leaves may get as much sunlight as possible? Look at the pattern of the leaves in the nasturtium plants shown on page 198. If you watch the leaves of a plant which is growing in a pot in a window, you will notice not only that the stems bend toward the light but also that the leaves on the stems keep turning so as always to face the sun as it moves across the sky.

What do you suppose would happen if you turned a window plant around to a position in which the leaves were not turned toward the sun? Try it sometime and see.

An experiment will show you exactly how important sunlight really is in the lives of green plants.

Exercise. How to prove that green plants need sunlight: Plant four bean seeds in each of two flowerpots which have been filled with good moist soil. Place one pot in a warm dark cupboard or closet and the other in a window of a warm room. Water both pots each day. Watch the plants through an interval of a few weeks. Which pot produces the greener, or healthier, plant?

You may observe that the beans grown in the dark are taller after a week than the beans grown in the sunlight (see illustration on page 198). Their growth, however, is unhealthy. They are growing on the food which was stored in the seeds and not making new food for themselves. Even with plenty of good soil, moisture, and warmth, plants growing in the dark will in time use up the food supply in the seeds and then die. Later in this chapter you will learn why this is true.

[1]From Gager's *Fundamentals of Botany*, courtesy of P. Blakiston's Son & Co., Inc.

m what direction did the light come in each case when these nasturtium plants were sprouting?[1]

The nasturtiums on the left show how green plants grow so that each leaf is expose[d] to the light. The tall bean plants in the pot at the right were grown in the dark, th[e] plants in the other pot under normal conditions[1]

Green Plants Need Good Soil. Warmth, moisture, and sunlight are not all that green plants need for normal healthy lives. They also need good soil.

Exercise. Put four beans on a sponge which has been placed in an ordinary drinking glass, as shown on the opposite page. Keep the sponge moist and warm and in a sunny place. How tall do the sprouts grow before they die? Why do they die?

This experiment, like the earlier experiments in this chapter, will take some time to perform. Like the earlier experiments, it will prove *definitely* what you probably already believe in a general way to be true. You may ask, "Then why take the trouble to perform these experiments?" The answer is that *what we believe to be true is not always true.* At one time most people believed that the

[1]From Gager's *Fundamentals of Botany*, courtesy of P. Blakiston's Son & Co., Inc.

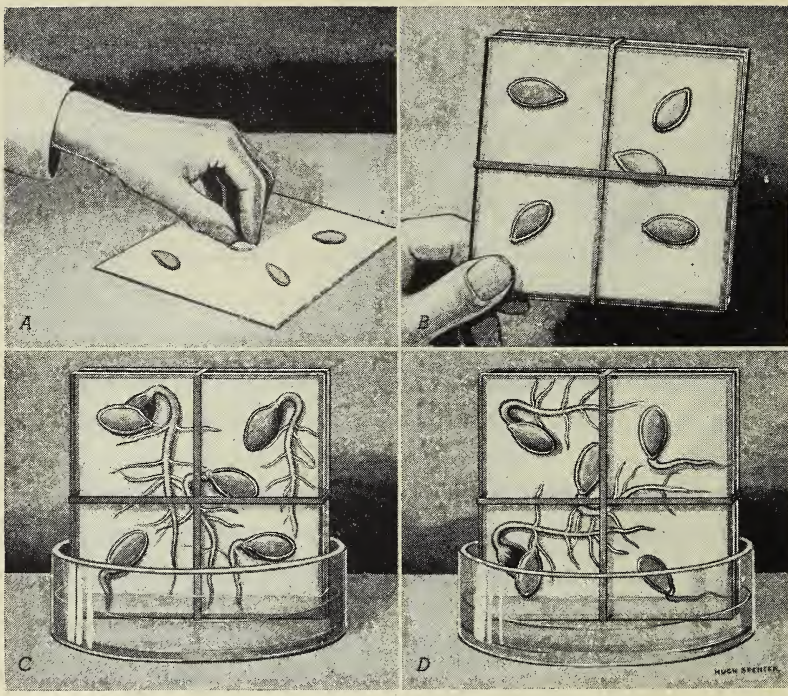
earth was flat—until a few brave sailors proved by observation and experimentation that it was round. The only way we can find out the truth of any of our beliefs about the earth and its creatures is to test them by observation and experimentation.

You probably know in a general way that plants take minerals from the soil; that without these minerals they cannot long remain alive. The above experiment will show you *exactly* how long a green plant can grow on the food which is stored in the seed without making any extra food for itself with the help of mineral material in the soil.

How Seeds Sprout. Once seeds begin to sprout, they do a wonderful thing. They grow with their roots downward and their stems upward. We can prove by a simple experiment that roots tend to grow toward the center of the earth and that stems tend to grow away from it.

Exercise. Mount some flat seeds of squash or pumpkin on a piece of blotting paper, as shown in *A* of the illustration on page 200. Press the blotting paper between two squares of glass and bind together with rubber bands or string, as shown in *B*. Place the edge of the bundle in a shallow dish containing a little water, so that the blotting paper

This boy is checking his record of the bean plants he grew on a sponge



This experiment will show how seeds sprout

and the seeds are kept moist (see *C*). Observe for several days. What is the direction of growth of the roots? of the stems? Next turn the bundle so that it lies in the water on another edge, as shown in *D*. Do the roots and stems continue to grow in the same direction as they did before the bundle was turned? If not, what direction do they take?

The plants in the above experiment act almost as if they were seeking the soil below and the sunlight above. On the blotting paper, of course, they cannot live very long. They soon wilt and die, as did the seeds which you made sprout on a moist sponge. Under more natural conditions,

however, most plants find mineral food in the soil and sunlight in the air. Roots are fitted, or *adapted*, to grow in the soil and leaves to grow in the air. Obviously, therefore, green plants could not grow with their roots upward and their leaves downward.

The Gifts of Spring. Warmth, moisture, and sunlight are the gifts of spring to the world of plants. Through these gifts the seeds and buds can wake up to life after their winter sleep. Roots reach into the softening ground and leaves into the warming air for the foods which make continued growth possible. The brown earth turns greener and greener until the full richness of summer is upon the land.

ACT II · SUMMER

The Season of Greatest Activity. As the spring days lengthen into summer days, the plant world becomes busier and busier. This increasing activity is produced by the sun. In summer the days are not only longer in our latitudes than during any other season; they are also brighter and warmer. In summer nearly twice as much heat and light reach the north temperate zone as in winter. It is this difference in heat and light that makes the plants so active in summer and so idle in winter.

These plants were grown in a liquid that contained the mineral materials which plants normally obtain from the soil. Notice the balance between stems and roots

Berenice Abbott

The summer activities of the plant world have to do very largely with two different kinds of work: the production of food and the production of flowers. Let us see just why and how green plants perform these tasks.

How a Young Plant Gets a Start in the World. If you make the experiment with the bean seed and the sponge, you will notice that the seed first splits into two parts. The young bean plant may be seen between these two halves. In time the stem grows upward and sends out leaves toward the light. The roots grow downward and into the openings of the sponge.

Outdoors in the soil the process of plant growth is the same. In the beginning a young plant has neither roots nor leaves. Its early spring growth is made possible by the food which is stored in the seed. In time the two halves of the seed wither away as the food that was stored there is turned into root, stem, and leaf.

If all goes well, the young plant becomes anchored in the soil in a few days. It develops many branching roots, and near the end of each root there will be delicate hairlike growths which are known as *root hairs*. Through these water and dissolved mineral matter enter the plant from the soil and pass through the stem to the leaves.

How Green Plants Make Food. The process of food-making begins in spring when the young plant develops green leaves and roots. It does not reach its peak, however, until the long warm days of summer. In earlier work in science you may have studied the process of food-making in plants. This process is so important, however, that it will do no harm to review it briefly here.

H. Armstrong Roberts

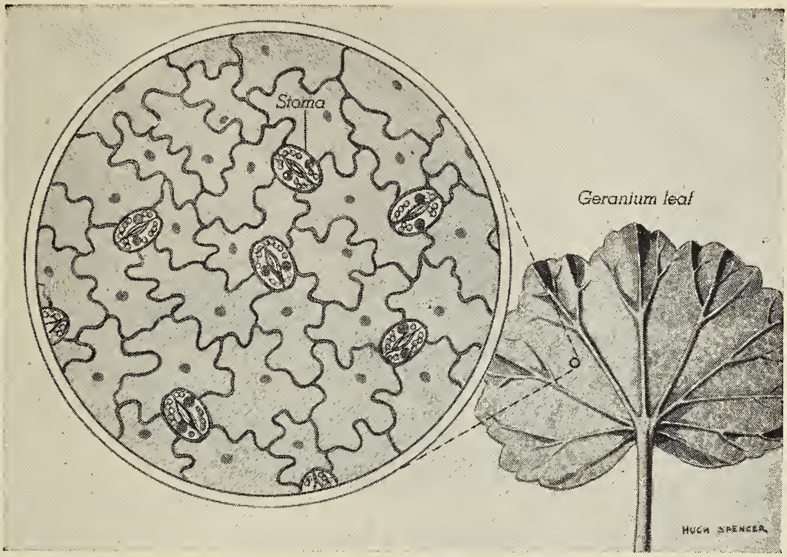
Summer is the season for work and play in the sunshine

As the plant grows, there is a continuous flow of water and dissolved mineral matter from the roots through the stem to the leaves. On the undersurfaces of the leaves there are little openings called *stomata* (singular, *stoma*), a word which means "mouths." The stomata are so tiny that they can be seen only with the help of a microscope. Small though they are, they perform an important work. Some of the water that comes from the soil passes out of the stomata and into the air. Do you see how, with the help of these little openings, a continuous flow of water and mineral matter can be kept moving through the growing plant?

The stomata do more than give off water to the air. Carbon dioxide enters the leaves through these tiny "mouths." It is from the water and the carbon dioxide in the leaves that the plant makes its food. With the help of sunlight and the green coloring matter in the leaves (*chlorophyll*), water and carbon dioxide are changed into sugar. Some of the sugar is later turned into starch and stored in the various parts of the plant.

This process of food-making in green plants is known as *photosynthesis*, which means "putting together with the help of light." It is one of the most mysterious processes in the world. No scientist knows enough about it as yet to perform it artificially in the laboratory. No animal can perform it naturally in the fields and woods, and that is why animals must depend upon plants for their food.

How Green Plants Make Flowers. Food-making, as we have seen, is only half the summertime work of the green plant world. Flower-making is the other half. Spring, to be sure, has its flowers, but they do not compare in abundance with the flowers of summer. Though we notice spring

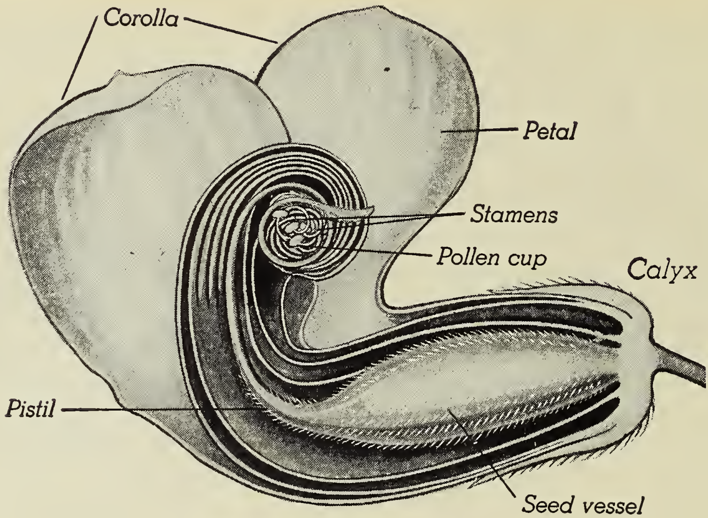


Green plants "eat" and "breathe" through tiny openings in their leaves

flowers more than those of summer, coming as they do after the long bareness of winter, the plant world does not get down to flower-making in earnest until the process of food-making is well under way.

If you follow the stages in the growth of a bean plant, you will see that after the roots, stem, and leaves are well developed, a bud takes form. Later the bud unfolds into blossoms.

The bud is covered with tiny green leaves which become the *calyx*, or base of the blossom. Inside the calyx are the delicately colored *petals*, which, taken together, make up the *corolla*. Inside the corolla are the *stamens*, and among the stamens is a single *pistil*. You have probably already studied the parts of a flower in earlier work in science, but look at the diagram on the following page to refresh your mind on this subject.



The parts of a bean flower

Just as food-making is necessary to give green plants life *this* year, flower-making is necessary to give them life *next* year. The chief business of flowers is to produce seeds which can live through the winter and give rise to new plants in the following spring.

How Flowers Are Fertilized. Notice in the diagram above that there is a *pollen cup* on the end of each of the stamens. In these cups a fine dry powder (*pollen*) is produced. *In order that a bean plant may produce seeds, the pollen of one flower must get into the pistil of another flower.* In some plants pollen is carried from stamen to pistil by the wind. In bean plants it is carried by insects, generally bees.

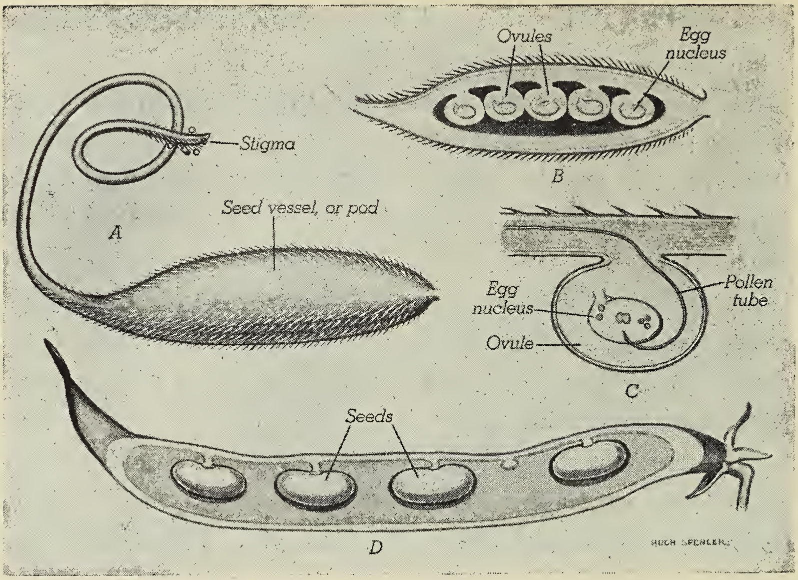
The bee visits the flower to gather the sweet liquid (*nectar*) which lies far down inside the flower. To reach the nectar the bee must force its way between the petals and stamens and over the upper end of the pistil. As the

bee burrows down to reach the nectar, its body becomes well dusted with grains of pollen.

In the mature bean flower the upper end of the pistil is covered with a sticky material. As the bee crawls in between the petals, some of the pollen grains gathered from the stamens of one flower are left on the sticky end of the pistil of another flower. This transfer of pollen from the stamen of one flower to the pistil of another is called *cross-pollination.* As soon as the pollen grains have been deposited on the sticky part of the pistil, other things begin to happen.

The pistil itself is complex, as you can see from the illustration on page 208. The sticky end on which pollen is deposited is called the *stigma* (see *A*). The base of the pistil is somewhat enlarged. This enlarged part is called the ovary, and it becomes the *seed vessel, or fruit. The fruit of the bean and certain other plants is called the pod* (see *A*). Within this enlarged portion of the pistil are undeveloped seeds called *ovules,* and within each ovule is a tiny part called an *egg nucleus* (plural, *nuclei*) (see *B*). In order that an ovule may develop into a seed, the egg nucleus within it must combine with a *sperm nucleus* from within a pollen grain.

To make this possible, some of the pollen grains deposited on the stigma by the bee develop *pollen tubes,* which extend downward into the seed pod at the base of the pistil. One of these tubes will penetrate the egg nucleus in the ovule (see *C*). From each pollen grain that finds its way into the stigma of a flower two sperm nuclei develop within the pollen tube. When the tube has reached the egg nucleus, one of the sperm nuclei unites with the egg nucleus. The union of these two nuclei is called *fertilization.* The cell formed by the union of the egg nucleus and



These drawings explain how flowers give rise to seeds

the sperm nucleus is called a *fertilized egg*. The fertilized egg develops into the *embryo*, which is part of the *seed* of a new bean plant (see *D*). After fertilization the petals of the flower fade and fall away.

How Seeds Are Made. There are several ovules within each flower, as shown in *B* of the illustration above. Each ovule will develop into a seed if the egg nucleus within the ovule is fertilized. If fertilization does not take place, there can be no seeds. In some bean pods you may find spaces for seeds in which no seeds have developed. Look at *D* of the illustration. The seed is missing because the ovule in that position was not fertilized.

The seed which grows from the ovule of the bean is dry when ripe and is surrounded by a thick *seed coat*. The tiny

embryo inside this coat will develop into a new plant when the seed sprouts. After the seed sprouts, the food which is stored around the embryo will keep it alive until the young plant has time to send roots down into the soil and green leaves up to the sunshine.

ACT III · AUTUMN

The Turn of the Year. Slowly, almost unnoticeably, the long warm days of summer begin to grow shorter and cooler. The energy which brought the plant world along from the seedlings of spring to the flowers and seeds of summer begins to let down. It is the turn of the year, when the earth and the green things on its surface are preparing for their long winter sleep. It is autumn.

The Season of Fruit. Just as spring is especially a season of leaves and summer a season of flowers and developing seeds, autumn is especially a season of mature seeds and fruit. After the flowers are fertilized, the enlarging seed pods keep insects from reaching the nectar which so many different kinds of green plants make. The nectar, however, does not go to waste. In many cases this sugary fluid is used by the plants to make fruit.

Apples, berries, grapes, and many other kinds of plants have their seeds buried in soft sweet fruit. In this way the plants attract birds and other animals that eat the fruit. The seeds, which generally pass through the bodies of the animals in an undigested condition, are thus scattered far and wide over the land.

All green plants develop many more seeds than they could possibly need to keep their kind on earth *if all the seeds grew into plants.* Most seeds, however, never grow

into plants. Many different kinds of accidents may befall them. They may rot or be killed by the cold; they may be crushed or broken; they may be blown by the wind or swept by rivers into the sea; they may fall on ground that does not supply the conditions which they need for growth. In one way or another most seeds are destroyed. Only a few of the many that are formed actually grow and produce plants.

It is a great advantage for a plant to have its seeds scattered over a wide region. In that way there is more chance that a few of the seeds will find safe places to spend the winter and good places to sprout in the following spring. Plants with fruit profit from being eaten, because being eaten makes certain that the seeds will be widely scattered.

The Kinds of Fruit. Most people think of fruit as soft and "fleshy," and, indeed, many fruits are of this kind. There are such fruits as apples, pears, berries, oranges, and melons in which many seeds occur inside each soft fleshy mass. There are also such fruits as cherries, apricots, plums, and peaches, in which only one seed occurs, in the form of a "stone," inside each soft fleshy mass.

In addition to these there are also nuts, grains, and many "vegetables" which are really fruits though we do not ordinarily think of them as such. Walnuts, wheat grains, bean pods, squashes, cucumbers, pea pods, are fruits because they have developed from the ovary of the flower. So too are the pods of such plants as the milkweed. A few of the many different kinds of fruit are shown on page 212.

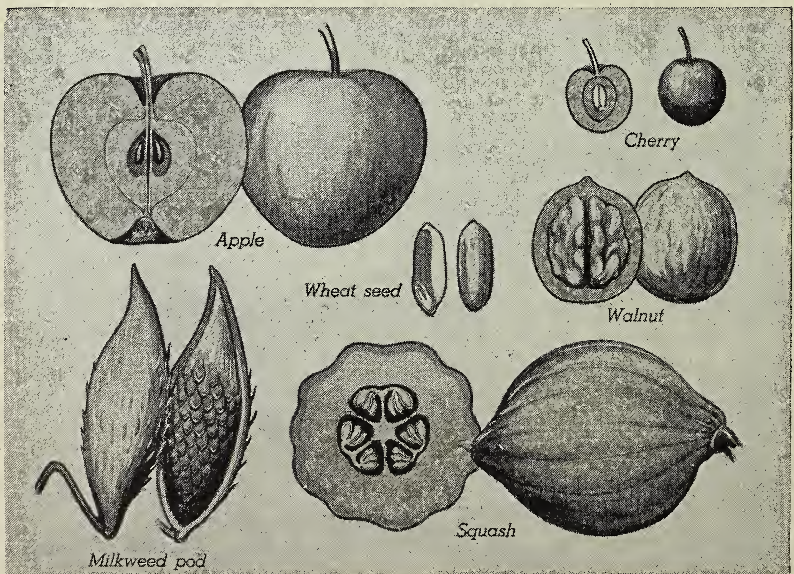
Exercise. Go to a grocery store and make a list of all the different kinds of fruit which you can find there. List as fruit anything that contains seeds.

J. Horace McFarland Co.

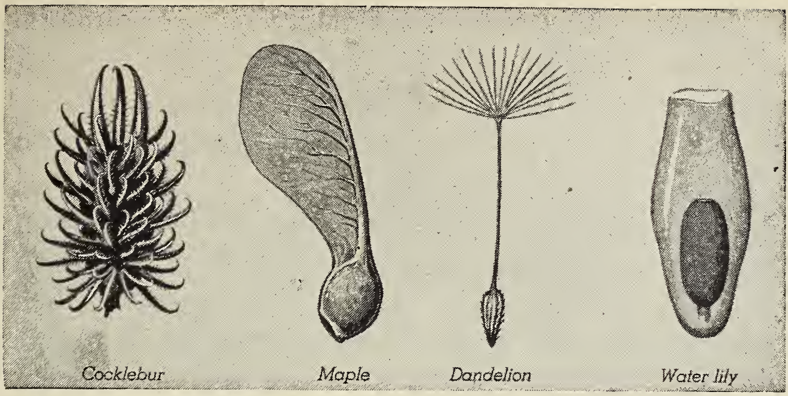
Autumn time is fruit time

How Seeds Are Scattered. Just as there are many different kinds of fruit, so too are there many different ways of scattering the seeds which fruit contains. Not all fruits are good to eat; so all plants cannot depend on animals to eat their fruits and thus scatter their seeds. Many plants, such as the dandelion, depend on the wind. The seeds of these plants are attached to some light feathery material which the breezes can carry long distances.

Has your dog ever come home with a burr in his ear? If he has, he was probably not very happy, even though he may have been doing a service to the plant that raised the burr. Many grasses and other plants of the fields have seeds which stick to the fur of animals and thus are carried from place to place. The seeds of certain water plants are slimy so that they stick to the feet of birds that wade in the water. In one way or another seeds are adapted so that



There are several different kinds of fruit



Seeds are scattered in various ways

they may be scattered and so that the kinds of plants that bore them will have a better chance of surviving from year to year (see illustration above).

Why Leaves Fall. Autumn is sometimes called the "fall" of the year, and this is a very good name for it. The most striking thing about autumn is falling leaves. "Evergreen" trees shed their leaves throughout the year, and new leaves are forming all the time. Other green shrubs and trees lose their leaves in the "fall."

We have already seen that leaves are factories which, with the aid of energy from sunlight, make sugar from water and carbon dioxide. All through the long summer days these factories keep very busy turning out their product so that the green plants can grow. As the days become shorter and cooler, the raw materials supplied to the leaves become less and less abundant. The factories slow down until they finally stop altogether.

Unlike many of the plants that die with the season of cold, shrubs and trees are adapted to live through it. As the

ground gets colder, there is less water moving about in the soil. What water and mineral matter the roots are able to take in must not leak out through the pores in the leaves. Any waste of food materials at this time would be harmful because lean months lie ahead.

Many people believe that water freezing in the delicate tissues of leaves causes them to wither and fall off. Scientists, however, know that this is not true. Before killing frosts attack a tree, green coloring matter begins to fade out and gold and red coloring matter begins to appear. What is left behind as the leaves get drier and drier is in a sense the beautiful ashes of the summer's activity. At last scars take form on the twigs where the leaves are attached and the wind blows the leaves to the ground. Their work is done and the tree is locked up against the winter cold.

ACT IV · WINTER

The Season of Rest. Earlier in this chapter we saw that the Drama of the Seasons was made possible by warmth, moisture, and sunlight. In winter the days are cold and often cloudy. The moisture in the ground is frozen so that the roots of plants are unable to make any use of it. The plants of the north are adapted to these conditions. The seeds produced in summer live through the winter and sprout in the following spring. The plants of the north, indeed, could not survive in a region where the winters are warm.

The Drama of the Seasons may seem a tragedy for the flowers of the gardens, the grasses of the fields, and the sedges of ponds and rivers. The cold of winter freezes the juices in the stems and leaves of such delicate growths and destroys them. But the seeds, and in some cases the

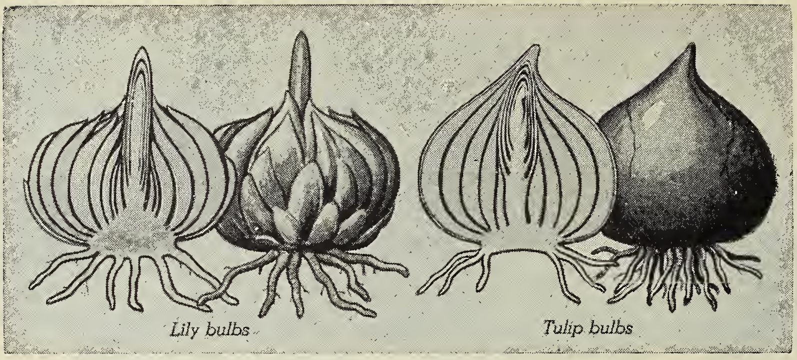
H. Armstrong Roberts

Winter is the season of rest for plants but not for men who must shovel snow

bulbs and roots, live through the cold and give rise to new plants in the spring.

How Green Plants Survive the Cold. The bulbs which many different kinds of green plants develop serve the same purpose as seeds. They lie idle through a period of harsh conditions and then give rise to new plants when conditions are favorable for growth. Crocuses, tulips, and many other early spring flowers grow from bulbs. As shown in the drawing on page 216, bulbs are short, thick clumps of leaves in which food is stored during summer. They become active very early in the following spring, producing leaves and blossoms before most of the plants that grow from seeds.

Dandelions, violets, and many other early flowering plants do not grow from bulbs but from roots which act



Bulbs are really short, thick clumps of leaves

like bulbs. Such plants also develop seeds, but those that appear earliest in spring grow from last year's roots. In the same way, part of the stem of the white potato plant enlarges into *tubers* which act like bulbs. These tubers, or potatoes, as we all know, are rich in stored food. Each "eye" is a bud and under favorable conditions will give rise to a new potato plant.

The shrubs and trees of the plant world, as we have seen, lose their leaves in winter. Unlike the more delicate garden flowers, grasses, and sedges, they do not lose most of their stems and roots as well. They do, however, have to draw within themselves in order to live through the winter. Twigs are hardened against the cold, and in many cases buds grow tough scales that keep their tender tissues from being blasted by the frost.

The branches of trees in winter may seem just as dead as the withered stems of flowers in the garden. But they are not dead (unless they have been "winter-killed" by extremely cold weather) and you can prove it. You are probably studying this unit in winter; so it will be easy for you to do so with the help of a simple experiment.

Exercise. How to prove that the branches of trees do not die in winter: Gather a few branches of willow, maple, hickory, or elm which contain some winter buds. Place them in a jar of water in a warm room. Do the buds swell after a few days? In a few days more do green leaves appear?

Winter is thus a time when green plants retreat into seeds, bulbs, and toughened branches to save their lives from the cold. It is also a time of rest. No living creature can go on living forever without rest. Plants, like animals, must slow down from time to time in order to repair the wear and tear of life.

So winter comes to the green plants as a blessing in disguise. Once safely walled away from the cold, they can take a much-needed vacation. Act IV of the Drama of the Seasons is thus really not an act at all. It is the intermission between two performances.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. If green plants are kept warm, they will grow in a healthy fashion without sunlight.

2. Moisture, warmth, and sunlight are all that are ever necessary to make healthy plants.

3. If seeds are planted upside down, they will grow downward into the earth instead of upward into the air.

4. In the spring green plants are busy chiefly with the production of flowers.

5. The process of food-making which goes on in the roots of all green plants is one of the most wonderful things in the world.

6. Bees are very helpful to many green plants because they carry pollen from the pistils of some flowers to the stamens of others.

7. When flowers are fertilized and seeds are formed, no more nectar is developed.

8. Green plants lose most of their seeds when their fruits, which contain the seeds, are eaten and digested by animals.

9. The fruit of green plants is always soft and "fleshy."

10. Autumn is called "fall" because temperature falls steadily from day to day at this season of the year.

11. Leaves fall from trees in autumn because frost freezes the water which the leaves contain.

12. "Bulb" is just another name for a large seed.

13. Only those plants that develop bulbs or seeds can live through the cold of winter.

Questions for Discussion

1. Why does a plant usually die when its stem is broken?

2. Is the bee the only insect that carries pollen from flower to flower? If you know of any other insects that do this, explain how they work.

3. Do you think that the life processes of plants that live in the temperate zones are the same as those of plants that live in the frigid zones? in the torrid zone? If you think that there might be differences, explain what you think they are.

Things to Do

1. Not all seeds sprout in the same way. Plant some squash, pea, bean, and corn seeds which have been soaked overnight in water. Note carefully just how each kind of

seed begins to grow in each case. Follow the process for four or five days.

2. Do you have growing plants in your classroom? If you do not have these attractive additions to your school, you may want to form a Garden Committee which will plant and take care of a schoolroom garden. Perhaps someone in your class has an older person at home who knows the kinds of plants that grow best in your locality. If not, a florist will probably be glad to help you.

3. In winter you may find flowers blooming in a greenhouse or in your classroom. Find the calyx, corolla, petals, stamens, and pistil. On the end of the stamens find the pollen cups. See if you can catch some of the pollen on a glass slide. Examine it under a microscope. Is the pollen of different plants alike?

4. If there is a good artist in the class, he may want to prepare some large wall charts showing the steps in the life history of a typical plant. If these charts are well prepared, they might be used by other classes.

5. Good reading on the life history of plants may be found in Kenly's *Green Magic* or McGill's *The Garden of the World.* You will also find Comstock's *Handbook of Common Flowers* of great help in identifying plants which you do not know.

CHAPTER NINE

How Do the Changing Seasons Affect Animals?

THE LIFE CYCLES OF FROGS, TOADS, AND FISHES

Life Cycles of Animals. In the last chapter we saw how the green plants play their parts in the mighty Drama of the Seasons. We saw that in general spring is a time of leafing, summer a time of flowering and seeding, autumn a time of fruiting, and winter a time of resting.

We shall now see how animals play their parts in this same drama. We shall see that animals, unlike green plants, do not play their parts in more or less the same way. Indeed, so differently do different kinds of animals meet the changes of the year that each kind is a story in itself.

The story of an animal from the time when it starts life in a tiny egg until it ends life in death is known as its *life cycle.* By studying the life cycles of various common animals we can get some idea of how differently different animals play their parts in the Drama of the Seasons.

How Frogs Spend the Winter. Let us study first the life cycle of the common frog, whose portrait is shown on the opposite page. In winter such frogs as this burrow into the mud of swamps and lakes. There, where the frost cannot reach them, they quietly wait for spring. The act of spending the winter in a low state of activity is known as *hibernation.* Many animals hibernate in one way or another, and in doing so they are not unlike the trees that spend the winter in an equally low state of activity.

If you were to dig up a hibernating frog from the mud, you would probably believe it dead. It would not stir and its heart would be beating so feebly that you would probably think that it was not beating at all. But if you took the body into a warm room it would soon begin to move. In a very short time you would have not only a live but a lively frog on your hands.

What Frogs Do in the Spring. As soon as the frost melts out of the ground and the water of swamps and ponds begins to feel the warm breath of spring, frogs come out of their winter hiding. Generally by March you may hear them croaking along the edges of ponds and small lakes. It is only the male frog that croaks. At this time the females are laying bunches of eggs in the water. When the eggs are laid the males cover them with sperm cells.

The egg of a frog is like the egg in the ovule of a flower. The sperm is like the sperm in the pollen of a flower. The egg and the sperm of flowers unite, as we saw in the last chapter, and a seed develops from the fertilized egg. In the same way the egg from a female frog and the sperm from a male frog unite. The union of egg and sperm—that is, fertilization—takes place in the water.

The number of eggs produced at one time by a large female frog may be as many as six or eight thousand. These eggs are arranged in a jellylike mass, as shown on page 222. The number of sperms produced at one time by a male frog is even greater. Why do you suppose, with

This common bullfrog spends the winter buried in the mud

A. M. N.H.

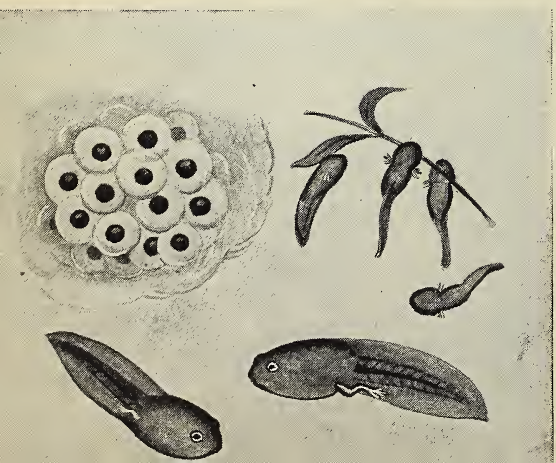
so many eggs and sperms, there are not a greater number of frogs in the world?

The fertilized egg does not give rise directly to a young frog. As many of you probably know, it gives rise to a *tadpole*, or *polliwog*. A young tadpole looks like a fish, for it has gills for breathing and a tail for swimming. In the water it leads an active life, feeding upon small plants and animals. If things go well, the tadpole is fully grown in about eight or ten weeks.

As the tadpole grows it sprouts the legs of a frog. Inside, lungs are developing, which in time will take the place of the fishlike gills. Still later the gills and tail disappear and the tadpole becomes a frog. It crawls from the water for a life on land. Though it may often return to the water, it will never again breathe water like a fish. Some of the steps in this life cycle are illustrated below.

What Frogs Do in Summer and Autumn. By the time frogs begin to breathe through lungs in early summer, insects are abundant. The frogs spend much of their time catching and eating the insects. In their turn, frogs are eaten by herons, muskrats, and snakes, which also live in the marshy land near streams and ponds. But with their powerful hind legs, which are good both for swimming in the water and for jumping on the land, frogs are well fitted to hold their own against their enemies.

These are the egg and tadpole stages in the life of a frog



When cold weather comes in autumn, frogs are no longer heard croaking in the marshes. They have buried themselves in the mud to

A.M.N.H.

Though mature frogs breathe air, they live in or near the water

spend the winter just as their parents did the winter before. Year after year this same cycle of events is repeated. "Cycle" means "circle." Do you see that in repeating the events of their lives from year to year, frogs move, as it were, in a circle? "Life cycle" is therefore a good term to use in referring to the way they meet the changing seasons.

Exercise. In early spring see if you can find some frogs' eggs along the edge of a pond or brook. Bring them to class and put them in an aquarium or a glass jar. Watch them grow from eggs to tadpoles. Make a record of your observations in a booklet called "The Life of a Frog."

The Life Cycle of the Toad. Toads are somewhat like frogs, but it is easy enough to tell the two apart. Contrast

the photograph of a toad below with the photograph of a frog on page 221. The toad's body is covered with "warts," while that of a frog is smooth. Some superstitious people believe that a toad can "give" them warts, but this is not true. The toad keeps all his warts to himself, as you can see!

The toad is unlike the frog in that it spends most of its time away from the water. It is a common animal in the garden and on the lawn. As the cold of winter approaches, the toad crawls into a hole in the ground or under a stone or a log. There it hibernates just as does the frog. When spring comes it awakens from its deep sleep and goes about its business once again.

As soon as toads leave their winter quarters they move to some near-by lake or pond. No one knows how they find their way to water, but they get there none the less. In the water the females lay eggs which the males fertilize with sperms, just as frogs do. A frog's eggs are held together in jellylike masses which resemble tiny bunches of grapes, but a toad's eggs look like beads on a string. A toad's eggs also differ in appearance from a frog's eggs in being entirely black. Frog's eggs are white except for one black spot.

Notice the eggs in the photograph on the opposite page. A female toad may lay as many as twenty thousand eggs; the male toad, like the male frog, lays many more sperms than the female lays eggs. After the eggs and sperms are laid, the toads leave the water for the dry land from which they came.

The toad is a "warty" edition of the frog

Cornelia Clarke

In the water some eggs and sperms unite, and the union forms fertilized eggs. The fertilized eggs develop into tadpoles. These tadpoles develop in much the same way as do frog tadpoles. In a few weeks they change to lung-breathing toads, which crawl out of the water. After they leave the water they move away from it and spend the remainder of the summer on dry land. When winter approaches they, like their parents, crawl into a hole and remain in hibernation until spring.

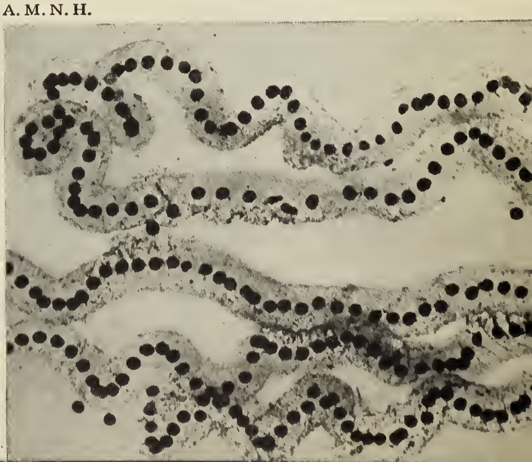
Cold-blooded Animals. Toads, frogs, salamanders, and certain other animals are known as amphibians. The word "amphibian" means "leading two lives." An amphibian, in other words, is an animal that spends part of its life breathing water and part breathing air. Amphibians are hatched in water and live there through a tadpole stage. They differ from many other animals in that the temperature of their blood is about the same as the temperature of the air or water in which they live. For this reason they are said to be *cold-blooded.*

The temperature of the blood of *warm-blooded* creatures changes very little with changes in the temperature of the air or water in which they live. Birds and dogs are warm-blooded, and so are human beings. Whether the temperature of the air around a man is ten degrees below zero or "one hundred in the shade," the temperature of the man's blood remains at about 98.6° F.

The temperature of the blood of an amphibian, on the other hand, may be 105° F.

A toad's eggs look like beads on a string

A. M. N. H.



A. M. Jackley, Pierre, So. Dakota

These rattlesnakes have just come out of their winter den

or possibly higher on a hot day. On a cold day it may be nearly (but not quite!) as cold as the freezing point of blood. When these animals hibernate they must find places where it does not get cold enough to freeze them, for in that case the cells in their bodies would burst. They are not always successful in this, and during unusually cold winters many hibernating animals are frozen to death.

Reptiles (turtles, lizards, snakes, and alligators) are also cold-blooded animals. They differ from amphibians in breathing through lungs during their entire lives. Reptiles that live in the temperate zones hibernate in winter. Turtles bury themselves in the mud. Snakes and lizards curl up in holes in the ground or under stones. Some snakes seem to have favorite ledges or "dens" to which they go year after year. Twenty or thirty snakes may hibernate in one den, as you can see in the photograph above.

The Life Cycle of Fishes. Most of the fishes of the temperate zones, like most other animals that live where seasonal changes are marked, lay their eggs in the springtime. At this season trout leave the ponds and travel upstream into water that is cold and rich in oxygen. The females lay their eggs in little hollows which they have carefully scooped in the sandy bottoms of brooks. After the eggs are laid, the male trout covers them with sperm cells, just as male amphibians do.

Salmon live in the ocean until breeding time. In spring a mysterious urge, which scientists do not fully understand, comes over them. They seek the far-off headwaters of fresh-water rivers in which to lay their eggs. The swim upstream by the millions, even jumping over waterfalls where these are in their way. Most salmon never live to make the journey back to the ocean, but the young go down the rivers the following year and remain in the ocean until they have grown up.

Since you probably know that most fishes lay eggs, you may be surprised to learn that a few kinds do not. These include certain tropical fishes such as "guppies" and Mexican swordtails, as well as sharks and certain kinds of minnows. With these fishes the sperm cells are not laid in the water but in the bodies of the females, where the young fishes are hatched.

This elevator was built to carry salmon over a dam so that they might reach the headwaters of the river and lay their eggs

U. S. Bureau of Reclamation

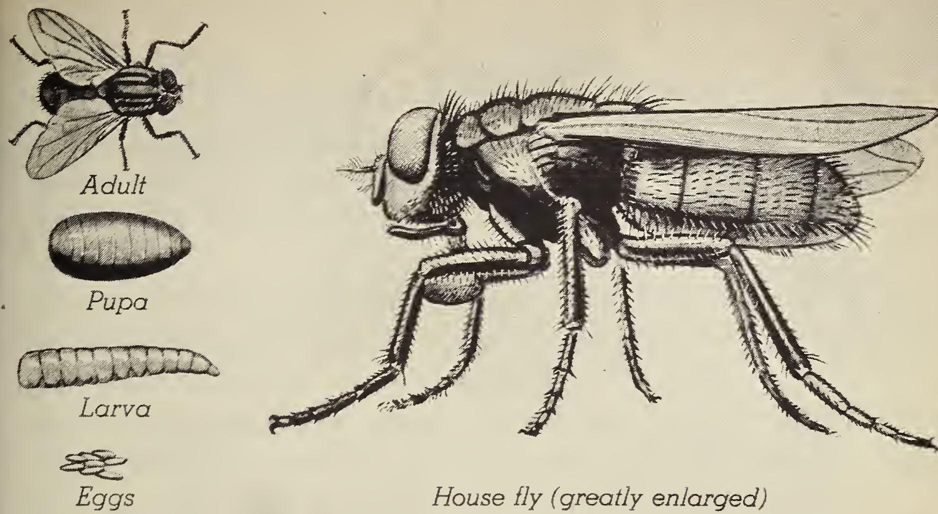
HOW INSECTS MEET THE SEASONS

The Abundance of Insects. Let us now observe the life cycle in another group of living things, the insects. In the temperate zones moths and butterflies, dragonflies, ants, lice, grasshoppers, houseflies, mosquitoes, gnats, bees, and many other insects are very numerous in summer. There are so many different kinds of insects in the world that more than a thousand kinds may live in your own back yard. Let us look into the lives of a few of them here.

Exercise. Build an insect cage and place a number of insects in it. See if you can keep them alive through the winter. Observe their eating habits, their methods of reproduction, and any other adaptations which they may show. Keep a record of your observations in a notebook.

The Life History of the Housefly. The housefly is one of the worst insect pests, although in many sections of the country it is now fairly well controlled. With the approach of cold weather most houseflies die. There are always some, however, that are able to live through the winter by hibernating in barns, attics, or other sheltered places. With the coming of warm weather these few awaken, and the females then lay their eggs. You know, perhaps, that the houseflies lay eggs in decaying matter such as garbage and barnyard manure.

A female housefly will lay more than a hundred eggs at a time and as many as six or eight hundred in the course of her lifetime. Under favorable conditions the eggs hatch into little wormlike *larvae* (singular, *larva*) in about eight hours. The larvae are commonly called *maggots*. They eat the filth in which the eggs are laid, and with a few days of warm weather change into quiet little rods which are known



There are four stages in the life cycle of the housefly

as *pupae* (singular, *pupa*). In this stage they seem completely inactive. They do not eat, but great changes are none the less taking place inside the hardened cases which surround them. After about four or five days in the pupa stage the fly comes out from the case.

Notice in the illustration above that there are four stages in the life cycle of a fly. These are the egg, the larva, the pupa, and the adult stages. Many insects pass through similar life cycles. In the case of the housefly about ten days pass between the time the egg is laid and the time the fully developed fly leaves the pupa. When the weather is cool it takes longer for these changes than when the weather is warm.

You may ask why there are so many flies in the world. A little figuring will answer your question. Suppose that a female fly lays eggs but once during her lifetime. Let us say that she is the average age of houseflies when they lay their eggs (about ten days old), and that she lays the average number of eggs (about 100). Let us say that half of

these eggs develop into males and half into females. Within twenty days from the time the first eggs were laid each of the fifty female flies may lay 100 eggs. When these hatch, there are 5000 flies.

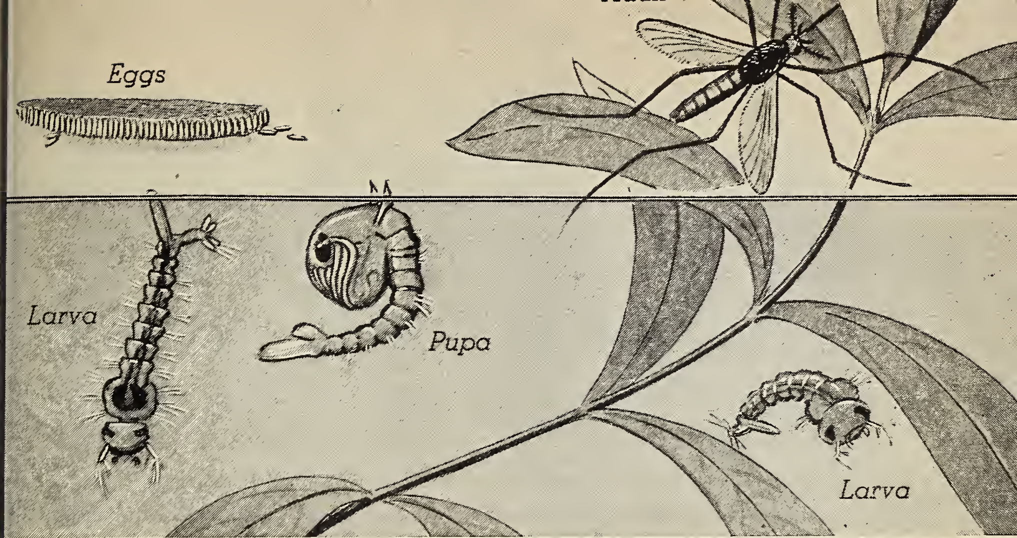
Suppose that half of these 5000 flies (2500) are females and that each female lays 100 eggs. When these hatch, there will be 250,000 flies. Twenty days later there may be 50 times more, or 12,500,000 flies. *Thus a single fly may become an ancestor to nearly thirteen million flies in less than three months!* Each of the other three or four batches of eggs laid by a single fly will, if conditions are favorable, result in an equally large number of flies in four generations. Now do you see why there are so many flies?

It is not likely, of course, that all the eggs will hatch into flies. Houseflies are such despised little creatures that measures have been taken to control their breeding. In large cities garbage or manure which is left uncovered is quickly removed and destroyed. Flies' eggs may be laid on it, but the whole mass is destroyed before there has been time for the eggs to grow into flies.

If these flies have typhoid-fever germs on their feet, this child is in serious danger

F. S. A.

The worst feature of the housefly is that it may spread diseases, particularly typhoid fever. The germs of typhoid fever are in the excretions, or discharges, that have come from the bodies of persons who have the disease. Flies may feed on these excretions and carry the germs from

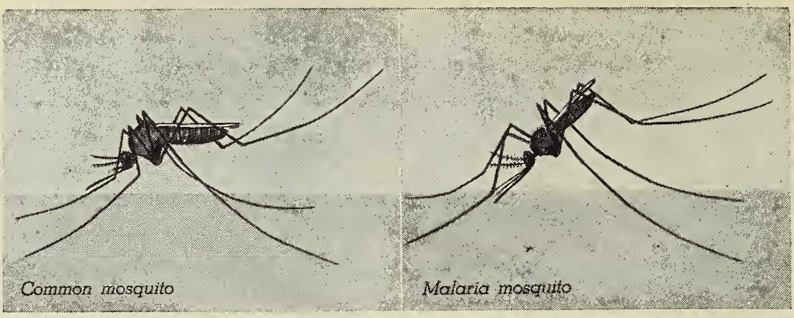


The mosquito, like the housefly, passes through four different stages of growth

where they feed to the food on our table. It has been shown again and again that cases of typhoid fever are most abundant in the United States during August and September. This is also the time when houseflies are most abundant. It has been proved that houseflies may carry the germs of typhoid fever from filth to food.

It is easy to see that a campaign to prevent flies must be a campaign to clean up filth. No amount of swatting will do much good if manure piles or decaying garbage are left for flies to breed in. Both as larva and adult, the housefly cannot live without filth.

The Life History of the Mosquito. The mosquito is another disagreeable insect. Most mosquitoes are killed by frost, but, as in the case of the fly, some are able to live through the winter. In the early spring the females lay their eggs. Unlike the eggs of flies, the eggs of mosquitoes are laid in pools of still water. They hatch to form *wigglers*, or "wiggle-tails," which are common names for the larvae.



Beware of the mosquito that tilts its body when it stings

In this form the mosquito grows very rapidly by feeding on tiny plants and animals that live in the water. The pupa, the next stage in its development, does not eat and is much less active than the larva. From the pupa comes the mature mosquito. It crawls from its case and perches upon it until its wings are dry. It then flies away as a full-grown mosquito. The four stages of this life cycle are shown on page 231.

Strange as it may seem, mosquitoes feed mostly upon juices which they suck from plants. It is only the females that ever attack us, but these quickly leave their plant food to feed upon man or other creatures when they can. Only the females that suck blood can lay eggs. The males cannot suck blood because their mouth parts are not built for piercing skin.

All mosquitoes are disagreeable, and no one likes any of them. Some forms are more than disagreeable; they are dangerous because they may carry disease. The common mosquito of the northern part of the United States (called *Culex*) is harmless in the sense that it does not carry disease. In the Southern states there is a mosquito which may be very dangerous. This one (called *Anopheles*) may carry malaria.

These two kinds of mosquitoes are shown at the left. Notice that the malaria mosquito tilts the hind part of its body upward while sucking blood, and that the harmless mosquito does not. There is another kind of mosquito that may carry yellow fever. This kind is common in Central America, but it is seldom found farther north than the states that border the Gulf of Mexico.

The prevention of malaria and yellow fever depends on how well the breeding of mosquitoes is controlled. The common northern mosquito, although it does not carry disease, is so objectionable that it too should be controlled. All mosquitoes breed in water that is not moving. It is clear that the way to control mosquitoes is to drain swamps and to remove tin cans and other containers in which water may stand after a rain.

Exercises. Prepare a list of rules for the control of mosquitoes, flies, and other insect pests. If your list is a good one, it might be copied and distributed to the people in your community.

Get some outline maps and indicate the regions in which yellow fever and other insect-carried diseases are now common or were once common. See if you can find out why these particular regions are or were affected by these diseases.

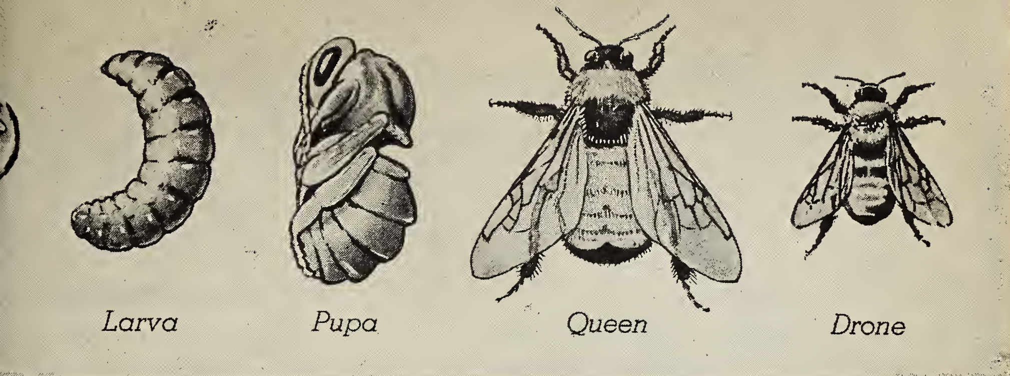
Helpful Insects. Not all insects are harmful. Bumblebees, honeybees, ladybird beetles, dragonflies, praying mantises, and silkworms are among those which may be very helpful to man and to other living things. Without bees many flowers would fail to produce seeds; for, as you know, bees carry pollen from flower to flower. The importance of the bumblebee is well illustrated when we realize that this insect pollinates the flowers of red clover and kidney beans.

Without bumblebees neither of these common plants could produce seeds. Ladybird beetles, dragonflies, and mantises live upon other insects and help to keep many destructive kinds under control. Silkworms produce the thread from which fine dresses are made.

The Life History of the Bumblebee. The life cycle of the bumblebee illustrates an interesting adaptation to the changing seasons. The stages in this cycle are shown on the opposite page. Bees live together in societies, and for this reason they are known as *social insects*. During the summer a nest or community of bumblebees is a busy place, but cold weather kills most of the inhabitants. Some of the females survive, and these are the *queens* of the next season. They live through the winter in hibernation.

A common place for a female bee to hibernate is in a rotting log or stump. She crawls into a tiny crevice as far as possible. In this way she is protected from the cold and also from hungry little mice and moles. She seems entirely lifeless during the winter months, but when spring comes she leaves her hiding place and seeks a place for a nest.

The place selected may be a hole in the ground which has been dug by a field mouse. The queen immediately builds a nest with many irregularly shaped rooms called cells. The walls and ceilings of the cells are made of pollen and honey taken from the flowers. In these cells the queen lays her eggs. The eggs hatch into wormlike larvae, which feed upon the pollen and honey stored in the cells. The food which has been stored in the nest is not enough to keep the greedy larvae alive for long. As they grow the mother is kept busy gathering more and more pollen and honey. In time the larvae turn into pupae, which do not eat, and after a while the pupae turn into adult bees.



These are the stages in the life cycle of the bumblebee

The bees of the first brood are all undeveloped females. They are a little smaller than the bees of later broods, and are known as *workers*. They are well named because they spend their lives gathering honey and helping with the work about the nest. The queen bee continues to lay eggs, and with the help of these workers some of the larvae are well fed. With plenty of food, these may develop into larger bees, some males and some females.

By midsummer the single queen that lived through the winter is the mother of a large colony. The males are known as *drones*. Compare the size of the queen with that of a drone bee, as shown above. The little drones gather food for themselves, but they do not work for the colony except to fertilize the eggs of the queen. The workers divide the work of the nest, some doing one thing and some another. Among them may be a few young queens that are developed enough so that they are able to lay eggs. These may add a little to the population of the nest.

The work of the summer season is a work of building up the colony. This season, however, is soon over, and when frost comes the workers and the drones are killed by the cold. The fertilized queens go into hibernation to sleep through the winter. Each spring and summer brings the

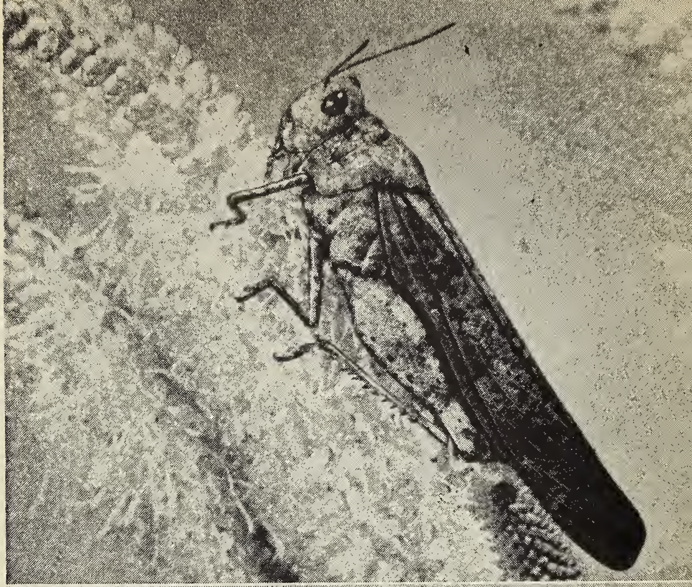
same round of events. A lone queen builds her nest, rears her young, and builds up a colony, all of which is destroyed by the cold when winter comes.

How Insects Spend the Winter. Most full-grown insects are killed by cold weather. Since there is never any shortage of these creatures in summer, however, it is clear that a few of each kind must live through the winter in one form or another. For example, grasshoppers similar to the one pictured on page 237 lay eggs in the ground before the winter comes. The adults are soon frozen to death, but their eggs hatch out in the following spring.

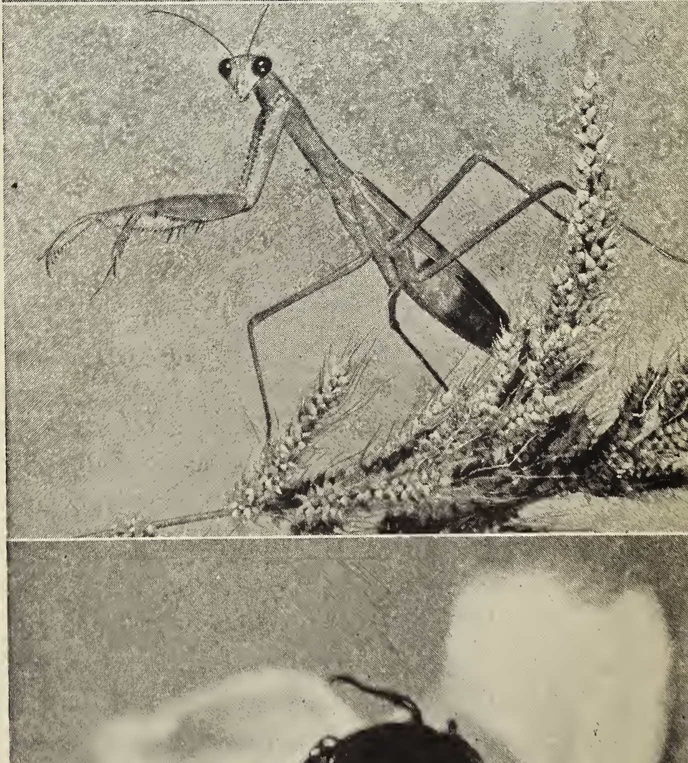
The praying mantis, shown on page 237, is a large insect that looks something like a grasshopper with a long neck. Like a grasshopper, it lives through the winter in the egg stage. The females lay masses of eggs about the end of September, which are attached to small twigs or weeds. Soon after the females have finished laying they die, as also do the males. In the warm springtime the eggs hatch, and little mantises begin a new cycle of mantis life. Do you see how all these life cycles are timed to match the seasons?

Most insect larvae are soft-bodied creatures that would certainly freeze during the cold winters of the north if left exposed to the cold. Some of these, however, live deep in the soil and are thus able to spend the winter in safety. The Japanese beetle, shown on the opposite page, is an interesting example of this.

After an active summer spent in chewing up the leaves of some of our most-valued plants, the females lay eggs in the soil. These hatch out in the fall, and the larvae begin to grow by feeding chiefly upon the roots of grass. They then bury themselves in the soil and remain inactive during the winter months. As soon as the soil becomes warm, they



This grasshopper will freeze to death in the fall, but the eggs will live through the winter



The praying mantis is really far from devout

The Japanese beetle is an expensive pest

Photographs by
Edwin Way Teale

take up eating again. Later in the spring the larvae turn to pupae, and the adult beetles appear about the end of June. These beetles (which, as their name indicates, are immigrants from a foreign country) are, unfortunately, well adapted to live through our seasons in North America.

The Life History of Butterflies and Moths. Most butterflies and moths spend the winter in hard, tough pupa cases. You may be able to recognize some of the larger *cocoons* or *chrysalises*, as the pupae are called, of our common butterflies and moths. The life history of the *Cecropia* moth illustrates an interesting adaptation to the seasons.

On one of your winter hikes you may notice on a twig a cocoon about as long as your middle finger and somewhat thicker near the middle. Have you ever seen a cocoon like the one on page 239? It has a thick brown silk covering which is so tough that it is difficult either to tear or to break it. If you take it home and save it until spring in a box out of doors, you will probably discover some day a fine brown moth which is decorated with robin-red spots. This is the handsome *Cecropia*.

Cecropia and other moths lay eggs on twigs or leaves. Small caterpillars hatch from the eggs. These greedily eat leaves and grow until their skins are so tight that they split down the back and peel off. But there is another skin already grown under the old one. This new skin can expand to a larger size than the first one.

The *Cecropia* caterpillars continue to eat and to shed their skins until they are a little thicker than a lead pencil and about three inches long. Then they stop eating, crawl to some near-by twig, and begin spinning a cocoon. When a caterpillar has surrounded itself with silk to the proper thickness, it sheds its last caterpillar skin and becomes a

Cornelia Clarke; Edwin Way Teale

ese photographs show the caterpillar, cocoon, and adult of the handsome Cecropia moth

pupa. Here it rests until spring, when it turns into a fully developed moth. All adult *Cecropia* moths die when winter comes; only those in the pupa stage survive. The stages in the life of this moth are shown above.

Exercise. Make a collection of cocoons for your classroom. Do any of them develop into insects?

HOW FEATHERED AND FURRED ANIMALS CHANGE WITH THE SEASONS

The Migration of Birds. You have probably noticed that a big difference between summer and winter in the north temperate zone is in the number of animals that one sees. In tropical lands animal life is always very noticeable. In

temperate lands it is very plentiful during spring and summer but much less so during winter. We have just seen what happens to the insects when cold weather approaches. But what happens to the other animals?

What happens, for instance, to the birds? The answer is that many birds that live through the summer in the frigid and north temperate zones fly away (migrate) southward when winter comes. When winter has passed, they return to their northern homes. Birds, indeed, are remarkable travelers. Some of them travel as far north as the arctic circle. The nest of the arctic tern has been found within eight degrees of the north pole. This bird, pictured below, nests and rears its young in a region where the summer sun never sets.

When the long arctic night begins, however, the arctic tern starts a journey southward which continues until the antarctic circle is reached and passed. It migrates from the Land of the Midnight Sun in June to the Land of the Midnight Sun in December and January. The shortest distance between its January and July homes is about eleven thousand miles. *This greatest of bird travelers thus flies over land and water some twenty-two thousand miles each year!* The map on the opposite page shows the migration routes of this and some other birds.

In the same way the bobolink nests in northern United States or southern Canada. When cold weather comes, it migrates southward along the Atlantic coast line to Florida, from Florida to Cuba, and from Cuba to South America. Having

The arctic tern travels twenty-two thousand miles every year

Allan D. Cruickshank

The summer and winter homes of certain birds are far apart

reached South America, it continues its journey across the equator to the valley of the La Plata River in southern Brazil. It thus misses cold weather by a wide margin.

The tern and the bobolink are not the only bird travelers. The month of September finds cuckoos, nighthawks, tanagers, vireos, kingbirds, wood thrushes, and many other birds on the way to warmer climates. Those of you who live to the south of the summer homes of such birds may watch them as they pass. At times they may be seen in very large numbers. Some make frequent stops, while others fly for great distances without a rest. Some fly by day, but many fly by night.

Exercise. In autumn count the birds on a moonlight night as they pass between you and the full moon. A good field glass will bring them out clearly.

A careful student of birds has reported that he once counted two hundred and sixty-two birds which flew across the face of the moon between the hours of eight and eleven. The birds were probably just as numerous throughout the sky as they were in the circle which was outlined by the moon. This observation gives us some notion of the number of birds that migrate with the change of seasons.

Perhaps you have seen flocks of birds similar to the one which is illustrated on the opposite page. Of course, not all birds migrate. Chickadees, nuthatches, woodpeckers, and certain others are adapted to live through cold, stormy weather, and they brighten the frozen northland with their presence. Some birds, such as the robin, migrate only short distances. Enough birds leave the north temperate zone in winter, however, to reduce very greatly the bird population of that part of the earth.

A. M. N. H. exhibit

Migrating geese make beautiful patterns in the sky

How Rabbits Live. Cottontail rabbits are among the most common animals in the north temperate zone. Rabbits neither hibernate nor migrate. They lead active lives throughout the winter. In spring they build nests, usually in shallow holes which they dig in the ground. The nests are made of dead grass and warmly lined with fur from the mothers' bodies. The baby rabbits born in the nest are helpless at birth and must be cared for until they are large enough to hop about and find food for themselves. Rabbits are very numerous because one healthy female may give birth to as many as fifteen or twenty young ones during a single summer.

Rabbits feed entirely upon plants. Since food is plentiful during summer and fall, they approach the winter well

fattened and in fine condition. Their fur thickens, too, and when cold weather comes they have a much warmer covering than they have in summer. Winter is none the less a hard season for rabbits, chiefly because food is scarce. If heavy snows come and cover the ground for long periods of time, many of them die from starvation.

How Squirrels Live. Some animals prepare for winter by storing food, and the squirrel is a good example of this type. Squirrels are active all winter, except during the very coldest weather, when they stay under shelter until the cold wave has passed. Their winter homes are nests in hollow trees, which may be lined with leaves and moss, paper, rags, fur, or other soft materials.

Squirrels store food in the ground or under the shelter of a log near a tree. When food is abundant in the fall, they may work all day and far into the night, laying up a winter supply. Is the picture below familiar to you? The hidden store may contain bushels of pine and spruce cones, as well as nuts, acorns, and corn. As you watch squirrels busily at work hiding nuts and acorns here and there in the forest, you wonder if all these morsels of food will be found again by the animals that buried them.

Squirrels fill their cupboards with food before winter comes

When spring comes, the squirrels change their feeding habits. In winter they eat only nuts and seeds. In spring and summer they eat twigs, berries, and insects. They also rob birds' nests. A single red squirrel may destroy as many as two hundred birds' eggs in a single season. Their victims include warblers, vireos,

thrushes, chickadees, and several other kinds of songbirds. Thus it is that where there are many squirrels there may be few birds. In the fall the squirrels go back to their diet of nuts and seeds and to their task of laying away a store for winter.

How Woodchucks Live. Woodchucks (sometimes called ground hogs) are hibernating animals. One is shown below coming out of its den in the ground. They feed on plants and do not spare the farmer's beans and peas. During the summer they eat heavily and become so fat that they can hardly walk. In September or October they crawl into their dens and enter into the deep sleep of hibernation.

In February or March they wake up, thin but very much alive, and begin the regular activities of spring and summer. The woodchuck has a reputation as a weather prophet. February 2 is known as Ground Hog Day, and the little creature always gets attention in the newspapers on that date. If the day is clear so that the animal can see his shadow, six weeks of bad weather are supposed to follow. According to the belief, the ground hog then returns to his den for another sleep. If the day is cloudy and he does not see his shadow, he realizes that the back of winter is broken and that he need not go back to sleep.

How true is all this? Obviously it is not true at all. There is no reason to believe that the ground hog knows when February 2 comes round or that he is able to study the weather on that—or on any other—day.

The marmot is a woodchuck that lives among the rocks of high mountains

U.S. Biological Survey

Exercise. If possible, find and bring into the classroom some hibernating animals. Build a hibernating box outside the window and arrange it so that the animal brought in can be observed from time to time.

The Importance of Seasonal Changes. What conclusions can you draw from the observations of this chapter? You can say that many land and water animals greatly change their manner of life with the seasons. In addition to the creatures which you have studied in this chapter, there are many others that have special ways of meeting the changes of the year in the temperate zones. Though no two creatures meet these changes in exactly the same way, all creatures are alike in that they meet them *in some way*. Indeed, changes in living to meet changes of the seasons are among the most common happenings in this changing world.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. All the different kinds of animals meet the changes of the seasons in about the same way.

2. "Hibernation" means going somewhere else to spend the winter.

3. Fertilization among flowers is entirely different from fertilization among animals.

4. Frogs and toads are the same except that toads do not spend any of their lives in the water.

5. The blood of a cold-blooded animal is always cold.

6. Though there are many *individual* insects in the world, there are only a few different *kinds* of insects.

7. The housefly is a dangerous pest, and the best way to get rid of him is to swat him.

8. Though the mosquito bites us, it never carries dangerous diseases, as does the housefly.

9. The larvae of mosquitoes are called polliwogs.

10. A colony of bees is a community in which the males do all the work.

11. Most adult insects spend the winter in burrows.

12. Rabbits, squirrels, and ground hogs all hibernate during the winter.

Questions for Discussion

1. If you shiver easily with the cold, is it proper to call yourself cold-blooded? If so, why? If not, why not?

2. One part of the work done in mosquito control is to pour oil or kerosene upon stagnant pools of water. In what ways do you think this helps?

3. What methods would you use if you wanted to study the habits of the migrating birds in your locality?

4. Do you think people ought to be actively interested in the conservation of wild life? Explain, using birds as an example.

Things to Do

1. How well do you know the animal life of your region? Do you know ten insects? ten furry animals? ten birds? How does each one live through the winter? Do they use the same food through the different seasons? Do you know any winter birds that are not found in your community in summer?

2. The map in this chapter on page 241 shows the migration routes of only a few birds. Perhaps you may like to know about others. See if you can find out about them. Chapman's *Travels of Birds* is a good book. Prepare maps showing the routes of some other birds. You may like to prepare an assembly talk on "Great Travelers among the Birds."

3. Make charts showing the life cycles of some of the animals discussed in this chapter.

4. The boys and girls in one school organized a "Mosquito and Fly Control Squad." They studied their community to find conditions which were favorable to the development of these insects. These conditions were discussed with the local health authorities and with the people responsible for them. Would you like to try such a piece of work?

5. Do you want some good books to read? Try some of Fabre's nature books, such as his *Life of the Spider*, *Life of the Fly*, or *Life of the Grasshopper*. You may want to read parts of Maeterlinck's *Life of the Bee*. Some people believe this the finest nature book that was ever written.

CHAPTER TEN

How Are Plants and Animals Adapted for Life in the Desert?

WHAT THE DESERT IS

The Lands of Little Rain. In the last two chapters we saw how beautifully many kinds of creatures are fitted, or adapted, to live through the seasons of the year. Seasonal changes, however, are not the only conditions to which creatures must be adapted if they are to remain on earth. There are strangely different climatic conditions to which plants and animals are adapted. Perhaps the most interesting of these is the climate of the deserts.

In Chapter VII we learned that the desert belts of the earth lie rather generally where the torrid zone gives way north and south to the temperate zones. The margins of the desert belts, however, are not regular. In North America deserts stretch their hot, dry fingers from the south deep into the western part of the continent. Large parts of California, Arizona, New Mexico, Nevada, and Utah are deserts, and the creatures that live there must be adapted to desert conditions.

How Death Valley Got Its Name. Some ninety years ago, in 1849, the eastern part of the United States stirred to the magic word "GOLD!" According to reports, nuggets of the precious metal were to be found along almost every river. A few spadefuls of dirt might contain a fortune. You can imagine the excitement this caused in the East! Thousands of people made hasty plans to leave for the far-

off western coast. They knew little of the hardships of such a trip, and cared even less. Gold was just waiting to be picked up, so "On to California!"

There were many routes. Even the shortest of them meant months of weary travel. There were no railroads across the continent and no highways, yet thousands of the gold-seekers set forth on the difficult journey. In spite of hunger, thirst, hostile Indians, and even death, long caravans of covered wagons crept along through unknown country in search of the fabled riches.

Not all the memories of those days are pleasant ones. Death Valley in California is one of the least pleasant. It lay across one of the routes to the gold fields, and is a silent reminder of the men, women, and little children who suffered there in 1849. Today, automobiles speed comfortably across this desert. Then, long trains of wagons creaked slowly over winding paths through barren rock and sand. The heat of the blazing sun was at times unbearable, and many died of thirst and sunstroke without getting even a glimpse of the promised land beyond.

Death Valley is the basin of an ancient lake, sunk between high and almost equally dry mountains. The valley is more than two hundred feet below the level of the sea. A few small rivers flow into the basin through deep canyons, but they soon disappear. Much of the water evaporates into the dry desert air, and the rest seeps into the loose sand and gravel of the basin floor.

The cool wet breezes from the Pacific Ocean are robbed of their moisture by the Sierra Nevadas before they reach Death Valley. They become as dry, and in summer as hot, as a blast from an oven. The result is that Death Valley is one of the driest and hottest regions in the world. A summer temperature of 120° F. in the shade is common,

Raymond W. Thorp

Death Valley is one of the driest places on earth

and the Weather Bureau has recorded 134° F. Within such desert areas the struggle for life is a struggle with the climate. It is a battle with intense heat by day, often with intense cold by night, and with extreme dryness at all times. Human beings are not adapted to live in comfort in such places.

People who have never seen or lived near a desert are likely to think of it as a vast barren plain of sand extending as far as the eye can reach. They are likely to think of it as having no plants at all and very few animals. Such a notion of the desert is far from correct. Deserts are as likely to be rocky as sandy. They are as likely to be hilly or even mountainous as they are to be flat. There are many plants and animals which are well adapted for life under the harsh conditions of the desert. But before we study the marvelous adaptations of desert creatures, let us get a good picture of the conditions to which they are adapted.

The Rainfall of the Desert. Look at the illustration on page 251. From this scene what would you say are the main differences between a desert and other types of country? Let us see.

The most outstanding difference is probably in the rainfall. In some deserts there is no rainfall at all for long periods of time. In certain parts of the Sahara, for example, rain does not fall for several years. In some parts of the American desert regions there is a fairly even *distribution* of rainfall, but the *total amount* in every case is very slight when compared with that of other kinds of country.

Some figures will help to show this difference more clearly. In the following table you will find the average monthly rainfall, in inches, over a long period of years at three points which are located in different regions. Indianapolis, Indiana, is a typical city in the middle of the north temperate zone; Yuma, Arizona, is in a typical desert; Iquitos, Peru, is near the equator in the western part of South America.

	Indianapolis	Yuma	Iquitos
January	3.0	0.4	10.2
February	3.1	0.5	9.8
March	4.0	0.4	12.2
April	3.4	0.1	6.5
May	4.0	—	10.0
June	4.2	—	7.4
July	4.1	0.1	6.6
August	3.2	0.5	4.6
September	3.0	0.2	8.7
October	2.7	0.2	7.2
November	3.5	0.3	8.4
December	3.0	0.4	11.5
Totals	41.2	3.1	103.1

Do these figures help you to explain such a typical desert landscape as is shown on page 251?

Bureau of Reclamation, U. S. D. I.
This hotel at Yuma, Arizona, has faith in the desert sun

Exercise. On an outline map of the world, and with the help of an atlas, color in all the land areas that have ten inches or less of rainfall each year. This will give you a good idea of how widespread desert conditions are.

The Temperature of the Desert. The temperature of desert regions differs in many ways from that of other regions. As you might expect, the temperature generally is much higher in a desert than it is, for example, in a region where the westerly winds bring frequent storms. The average temperature at Indianapolis over a long period of years is about 57.1° F., while at one point in the Sahara Desert it is 76.6° F. This is a difference of almost twenty degrees.

It is not true, on the other hand, that deserts are always hot. Temperature over a period of a year in the desert may have much the same range as it does in the storm belt of the westerly winds. The difference between the coldest and

the warmest months at Indianapolis, for example, is about forty-seven degrees. At one place in the Sahara Desert it is about forty-four degrees. At Yuma, Arizona, it is about thirty-six degrees. The desert, like other regions which lie twenty or more degrees away from the equator, has its cool months as well as its hot months.

One striking difference between desert regions and those which are open to the cyclonic storms of the north temperate zone is the tremendous range in temperature during the day. In Indianapolis and other cities in the westerly-wind belt a warm day may be followed by a cooler night, but the difference between the temperature of day and night is not really very great. A change of twenty degrees between day and night in Indianapolis is typical. In desert regions, however, such a change would be a small one.

Sometimes in the desert, evening may bring frost after a day which was very hot. At one point in the Sahara a temperature of 59° F. was recorded at sunrise, while at 2 P.M. the temperature had risen to 116° F. The reason for such an extreme daily range in temperature may easily be explained. The rays of the sun heat the sand and rock of the desert very rapidly, but the heat is not held for long. *Heat radiates from the ground much more easily into dry than into moist air.* As soon as the sun sets over a desert, the ground quickly cools and the temperature drops.

Desert regions, then, are very different from other

Snow may fall in winter on deserts that lie at high altitudes

Frasher's

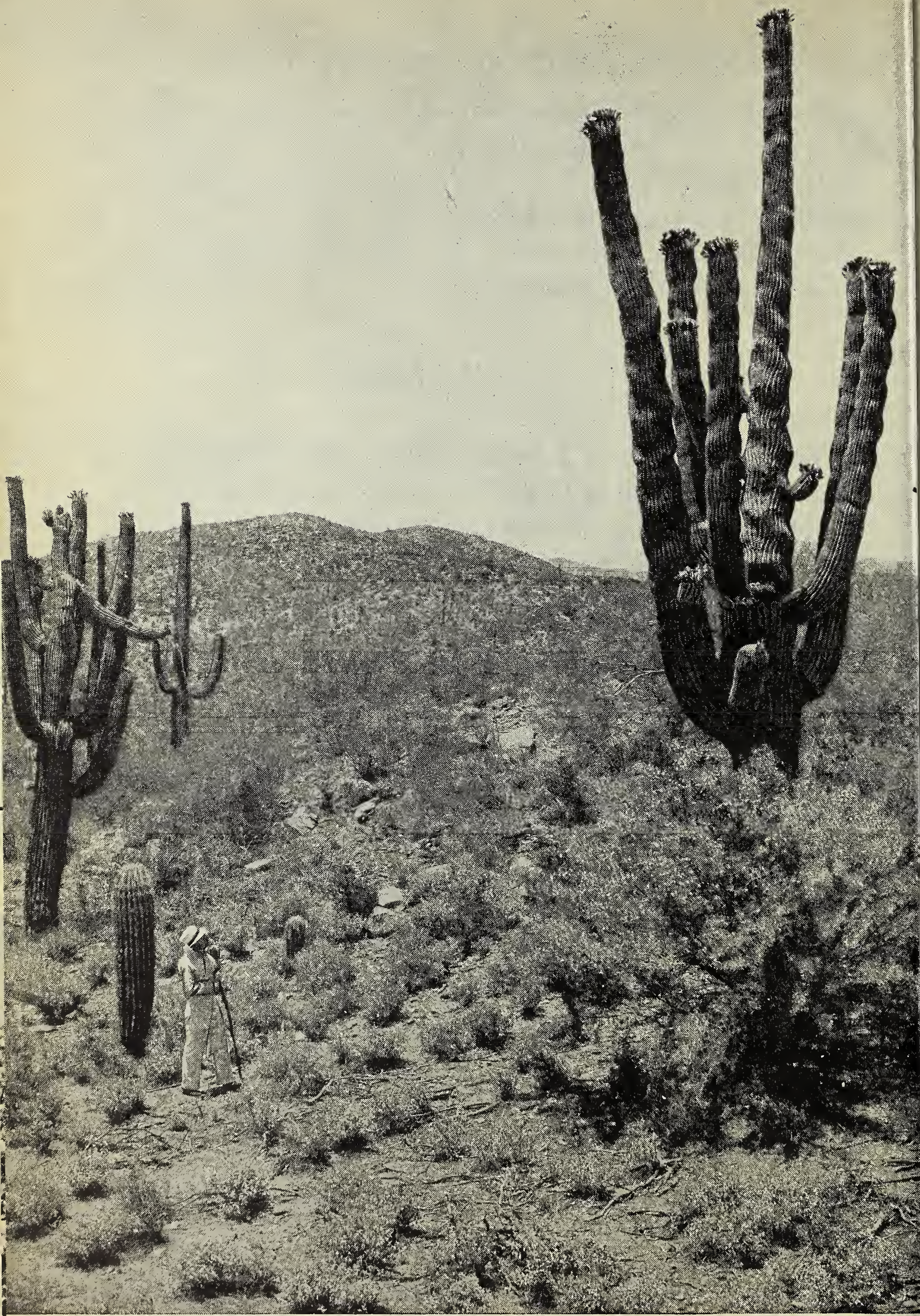
regions. Plants and animals must be adapted to long periods of dryness and, even under the best of conditions, to very little moisture. Furthermore, they must be adapted to extreme daily changes in temperature and to strong winds which blow during much of the year. Let us next study just what these adaptations are.

HOW PLANTS ARE ADAPTED FOR LIFE IN THE DESERT

The Giant Cactus of Arizona. As you probably know, every state has a "state flower." Some of these flowers are no doubt familiar to you, such as goldenrod, violet, sunflower, rose, appleblossom, bluebonnet, and rhododendron. There is one state flower, however, which is not very well known though it is one of the most beautiful flowers in North America. It is the state flower of Arizona, the bloom of the giant saguaro cactus.

If you are like many other people, you have only a faint idea of these mighty plants, and none at all of their flowers. As you look at the picture on page 256, you can see the short, thick, green stem of this cactus, somewhat like the trunk of a tree and in some cases more than a foot thick. A number of smaller branches grow from the main stem, all of which are covered with spines. In May the rounded ends of the branches are crowned with blossoms, creamy yellow and fully as large as saucers. Imagine flowers growing at the tips of thick prickly stems which are thirty, forty, or fifty feet tall!

The saguaro grows very slowly and may live to be more than a hundred years old. A certain specimen only eight inches high was known to be sixteen years old. The really old ones may be as much as sixty feet tall.



McCulloch Brothers

The state flower of Arizona grows on the tips of the weird saguaro cactus

How Desert Plants Are Protected against Dryness. Where are the leaves of the cactus plant? Suppose you take a look at a member of the cactus family from a position closer to the plant. Look at the photograph on page 258. Do you see the many short spines or thorns that cover the plant? These are the leaves of the cactus! Why do you suppose a plant of this sort is better adapted to live upon the desert than one with many broad leaves?

You have learned earlier in this unit that plants take in moisture through their roots and lose it through the pores in their leaves. As much as two tons of water may evaporate in one day from the leaves of a medium-sized oak tree. This means, of course, that the roots must take in two tons of water from the soil each day.

In the same way the roots of the cactus must take in as much water as the plant loses. But water is scarce in the desert, and desert plants are adapted to conserve it. The spines of the cactus, for example, are a special adaptation for saving water. Because spines present less surface to the air than do leaves, *the process of losing water takes place much less rapidly in spiny than in leafy plants.*

Exercise. How to show that spiny plants lose less water to the air than do leafy plants: Wrap up separately a small potted geranium and a small potted cactus plant in waxed paper. Place the two plants under a glass jar and allow them to remain there for a day or two. Is there any difference between the amounts of moisture which are given off by the two plants?

It is not enough that desert plants lose water slowly to the air. *They must also have special means of gathering water.* There is ordinarily so little moisture in the desert soil that plants must have very long roots for gathering it.

Some desert bushes have roots which burrow many feet into the ground. The deeper soil of the desert is less likely than the surface soil to be sucked entirely dry by the sun. Most desert trees and bushes can live from year to year only by tapping this deep supply of moisture.

Even by doing this the plants of the desert cannot afford to be wasteful of water. *They must have special means of storing it* in their bodies. Water is their wealth and they must save it—not for the rainy day of the proverb but for many rainless days.

One of the commonest bushes on our American deserts is the creosote bush. Its entire surface is covered with a greasy strong-smelling substance which helps keep the water stored in the plant from leaking into the air by evaporation. Other desert growths have thick, fleshy bodies which help them not only to hold their precious moisture but also to weather the extremes of heat and cold.

In a cactus plant spines take the place of leaves

Huntington Botanical Gardens, San Marino

Strangers traveling across the American deserts have died of thirst. Natives of these deserts do not meet this fate, partly because they know of a very unusual source of water. In many of our deserts the barrel cactus is common. This plant looks like a green barrel, and that is what it really is,—a barrel which stores water against the long periods of drought in a land of little rain. Such a cactus is shown at the left. When the experienced desert

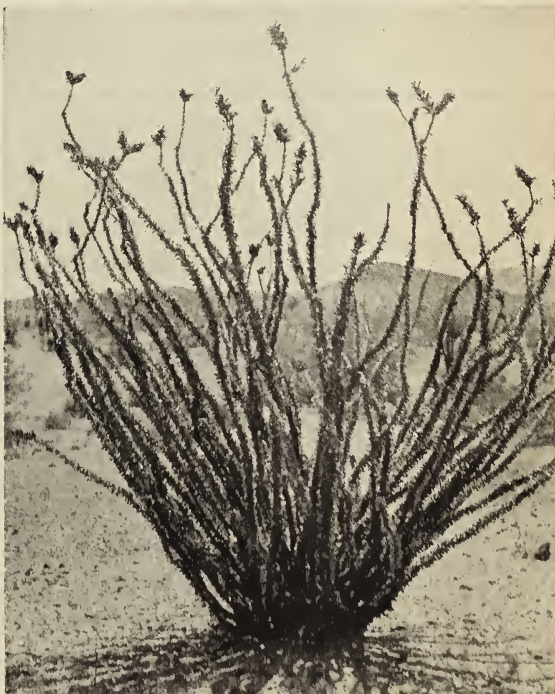
traveler is in desperate need of water, he may cut across the stem of a barrel cactus, gouge a hole in the pulp, and wait for the hole to fill with sap. In a short time the barrel will contain a lifesaving drink.

Do you see how the barrel cactus is like the woodchuck which we studied in the last chapter? The woodchuck stores fat against winter; the barrel cactus stores water against drought.

Other Desert Adaptations. Though getting and saving moisture is the greatest problem of desert plants, it is not the only problem. The wind is a real enemy of all living things on the desert. Sweeping down the canyons of surrounding mountains and across the wide open plains of the desert floor, it is an almost ever-present threat of destruction. Fortunately the adaptations of desert plants against drought play a double role because they are also adaptations against wind. All desert bushes and trees have spines or very small leaves which do not catch the wind. Most of them have long roots which anchor them solidly to the ground.

The leafless and "twigless" branches of the ocotillo plant are adapted to withstand the fierce desert winds

McCulloch Brothers



As we shall see later in this chapter, the desert is the home of many animals. These animals must eat, and many of them must depend on desert plants for their food. Most desert plants, however, are well protected against the attack of ani-

Howard L. Jones

Spring rains carpet the desert with gaily colored flowers

mals. With their spines and thick skins, and in many cases their bitter taste, they offer no real temptation to the appetite. The result is that such animals as depend on desert plants for a living eat chiefly the seeds.

Exercise. Get some small desert cacti plants from a nursery or a five-and-ten-cent store. With sand, gravel, a few stones, and some imagination, see if you can create a little desert landscape.

Spring in the Desert. Desert plants, like plants elsewhere, must produce flowers and seeds if they are to go on living. Unlike plants elsewhere, desert plants must produce them in a great hurry. Only in the few rainy weeks of spring is there enough moisture for carrying on this important business. Then the desert suddenly colors up in an almost miraculous manner. Cactus, greasewood, smoke tree, mesquite, and many other trees and shrubs become covered with beautiful bloom.

Shrubs and trees are not the only kinds of plants that live on the desert. There are many small growths that come up from seeds each year. These are small and all but unnoticeable throughout most of the year, but in spring they fill the desert landscape with breath-taking beauty.

During the short season of rain hundreds of square miles of the desert floor may become a solid mass of yellow poppies, purple lupines, pink verbenas, and many other small yearly growths. With them are the cacti with their pink, yellow, or red flowers, the strange ocotillo and Joshua trees, the Spanish bayonets with their single stiff spires of creamy bells which in many cases are twice as tall as a man. The photograph on the opposite page shows a flower-carpeted desert landscape. Odd as it may seem, there is no place on earth more beautiful than the desert when spring brings its precious gift of moisture.

HOW ANIMALS ARE ADAPTED FOR LIFE IN THE DESERT

The Horned Toad. Desert animals, like desert plants, must be tough. Have you ever seen a horned toad? If not, look at the photograph on page 262. These little creatures are well fitted to live in a harsh environment. Perhaps you

Raymond W. Thorp

The scorpion and the horned toad are neighbors but not friends

have read stories about how horned toads have lived for years without food or water. A horned toad was once said to have lived for forty years in the corner of a building where even the supply of air was limited. Such stories are not true. It is true, however, that horned toads and many other kinds of desert animals are remarkably well fitted to live through long spells of extreme heat and dryness.

The horned toad is not really a toad. It is a lizard. Its skin is tough and leathery so that it can stand dryness and heat as no real toad possibly could. It is protected from its enemies by its color, which matches the desert sand and bushes. When caught it flattens out on the ground like a stone, pretending to be dead. It can also stick up its horns and throw out a stream of red liquid which blinds its enemies long enough to allow an escape. It eats insects of many sorts, and gets along very well in spite of its unfriendly surroundings.

At a Desert Water Hole. Here and there in the desert, water comes to the surface of the earth through deep cracks in the ground. Little springs, or water holes, take form, and around them the plants and animals of the desert gather. Mesquite trees, palms, and a variety of grasses make these places spots of everlasting green. Shade on even the hottest day makes them fine places for the weary traveler to rest.

There is a certain water hole on the Colorado Desert in southern California where one of the authors of this book has many times pitched his camp. He has sat there for many hours trying to get acquainted with the creatures that live in the desert. From the cool shade of the palm trees he has watched the desert thrasher flitting in and out of clumps of prickly cactus, where the mother bird makes her nest. So expert is she in dodging the needle-like spines that she never gets pricked. Behind the spines her babies are safe from all harm because few other living creatures will willingly go near her spiny fortress.

The bayonets of the cactus guard the nest of the desert thrasher

H. L. Shantz

Aside from thrashers and wrens, a variety of brilliant hummingbirds, a few insects, and perhaps a lizard or two, the water hole is remarkably quiet and deserted by day. The reason for this is that *most desert animals go about only at night.* Each morning the sand round the water hole proves this fact. It is covered with footprints which tell many interesting stories.

There, for example, are marks which look just like the trail of a dog. But there is no house within many miles, so we know that no dog could have visited the place during the night—that is, no tame dog. The tracks are those of the wild dog of the desert, the coyote. Hunting jack rabbits, lizards, and mice, which also left their footprints on the sand near the water hole, the coyote was no doubt able to make his visit pay.

How Desert Animals Are Protected against Dryness. Desert water holes are few and far between and cannot be generally depended upon for water. Many rats, mice, ground squirrels, and other small desert animals never have a real drink of water as long as they live. *They are adapted for getting what moisture they need from their food.*

Moist-skinned animals are very rare on the desert. Frogs, leeches, and many insects that must live in water during part or all of their lives are rare if not entirely absent. Most desert animals have dry skins which are not harmed by the heat and the lack of moisture. Beetles, butterflies, centipedes, scorpions, spiders, birds, reptiles, and rodents—all with fairly dry skins—make up most of the animal population of the desert. Such creatures are toughened to live through long periods of intense drought without drying up.

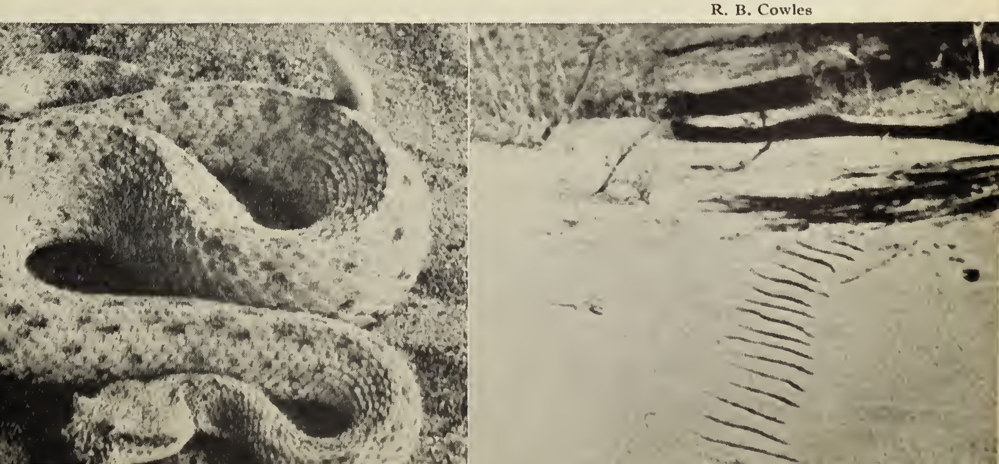
How Desert Animals Are Protected against Heat. In many deserts the stones get hot enough in the summer sun to fry eggs. Long exposure to such heat would be deadly to practically any animal. *The only good adaptation to extreme desert heat is to avoid it.* That, we have seen, is exactly what most desert animals do. They live in burrows by day when the sun is shining, and only come out at night after the sun has set. The few that are abroad in the daytime stay in the shade.

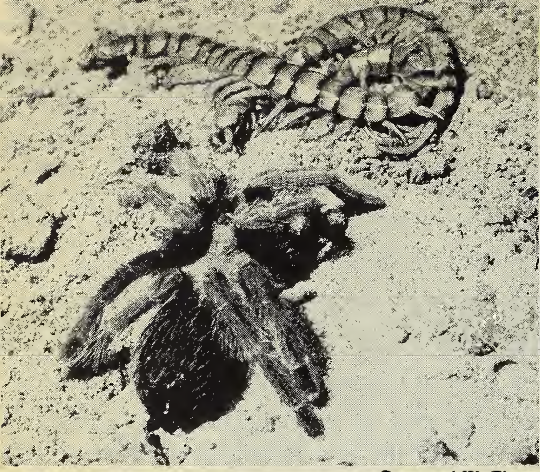
Perhaps you think of rattlesnakes as sun-loving creatures, but the rattlesnakes of the desert are anything but that. They fear the sun even more than you fear rattlesnakes. Indeed, only a few minutes' exposure to the hot summer sun of the desert will thicken the blood of a rattlesnake so that it dies. The rattlesnakes of the desert escape this fate because they do not come out of their burrows during the midday heat.

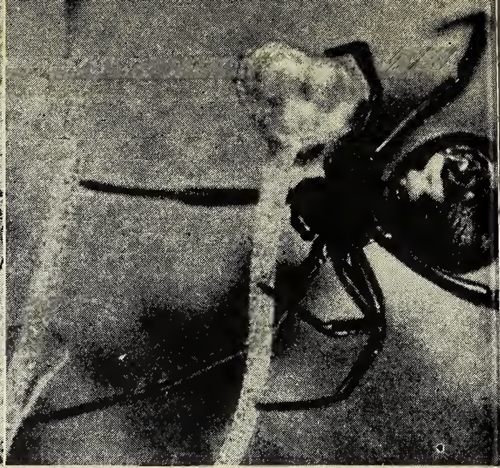
How Desert Animals Protect Themselves from Their Enemies. We have already seen how the desert thrasher escapes its enemies by seeking the protection of the spiny cactus bushes. We have seen how many other desert animals live in burrows. These animals are more or less safe from their enemies when they stay at home.

avoid slipping on loose sand and gravel the little sidewinder rattlesnake throws a coil of his body forward at each "step," thus making these strange tracks

R. B. Cowles







Raymond W. Thorp Edwin Way Teale

The tarantula and the centipede (left) look deadly, but their bites are generally not harmful to man. The black widow spider (right) is deadly poisonous

Several desert creatures are fitted with poison glands which they use when their hungry neighbors threaten them. The little "sidewinder" rattlesnake shown on page 265 is small but mighty. His poison is deadly to coyotes and in some cases even to man. It is wise when walking on the desert at night to wear leather boots because you might step on one of these rattlesnakes. As their name suggests, they do not coil before they strike, as most other rattlesnakes do, and for that reason are especially dangerous.

Very poisonous also is the black widow spider, shown above. This spider has been found in regions of heavy rainfall, but it loves best the dry hot places of the earth. It looks like a shiny black shoe button with legs, except for the red "hourglass" mark on the underside of the body. Fortunately the black widow is a gentle and lazy spider. It is almost impossible to tease one into biting.

Poisonous, too, is the Gila (pronounced hee′la) monster of the Arizona deserts. From the illustration on the opposite page you may feel that the title "monster" is a good one for this lizard which may grow to fully two feet in length. Then there is the tarantula shown above, a large

spider which paralyzes its insect and other animal food by a poisonous bite. Fearful stories have been told about the deadly tarantula, but its bite is not generally very serious for human beings. Other poisonous inhabitants of the desert are scorpions and centipedes, but the bites of these creatures are generally no worse than bee stings.

The Deserts of Asia and Africa. Though we have illustrated desert life in this chapter chiefly with examples from American deserts, the largest deserts in the world are in Asia, Africa, and Australia. Conditions in these deserts, however, are rather generally like those in the smaller deserts of North America.

Exercise. Look up and prepare short reports on The Gobi Desert of Asia, the Sahara Desert of Africa, and the desert region of central Australia.

One animal which is not known in American deserts is, nevertheless, the most famous of all desert animals. That animal, of course, is the camel. The chief beast of burden

The Gila monster is a large poisonous lizard of the Arizona deserts

A. M. N. H.


H. Armstrong Roberts
The camel is perfectly adapted for desert living

in the deserts of Asia and Africa, the camel is very well fitted for the life it leads.

It can eat prickly plants because its lips are hard and calloused. It can close its eyes and its nostrils to keep out the blowing sand. Its cushioned feet and tough skin protect it against both sand and heat. Its peculiar stomach is adapted for storing water so that it needs only one drink every three to five days. The hump on its back is a storehouse for fat which its body can draw on when food is scarce. With water stored in its stomach and fat stored in its hump, the camel can carry burdens over the driest and hottest desert at the rate of about twenty-five miles a day.

The desert is one of the best places in the world to study the wonderful adaptations of plants and animals which the

changing conditions on the surface of the earth make necessary. But the desert is not the only place where creatures must be specially fitted for special ways of living. In the next chapter we shall learn how plants and animals are adapted for an entirely different kind of life in an entirely different kind of place.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. All the deserts of the earth are in Asia, Africa, and Australia.

2. All deserts are vast barren plains of sand which extend as far as the eye can reach.

3. It rains on the desert as much as anywhere else, but the hot sun evaporates the water before it can soak into the ground.

4. All deserts are always very hot.

5. A change of as much as twenty degrees between the temperature of midday and midnight is very rare on the desert.

6. All the plants of the desert are very small.

7. Many desert plants have spines instead of leaves because spines are less likely to shrivel up in the heat.

8. Except for their spines, desert plants are much like the plants of wetter regions.

9. The desert is a brown land from the beginning of the year to the end.

10. The horned toad of the desert is the only toad that grows horns.

11. Desert animals can live indefinitely without moisture.

12. All desert animals love the hot sunshine, and may be seen sunning themselves on the sand in the middle of the day.

Questions for Discussion

1. Do you think that the desert regions of the world can ever become places of high civilization? Why?

2. Do you believe that cold-blooded or warm-blooded animals would suffer more from long exposure to the heat of the desert sun? Explain why.

Things to Do

1. Find out what effect deserts have had, and still have, upon world transportation and communication. How do people get about in the desert? Are present methods of transportation about the same as they were a hundred years ago? You may wish to find out something about old and new caravan routes. These routes could be traced on an outline map of the world.

2. Find out about what is being done in American desert regions by irrigation. Make a report to the class.

3. Find out about the work which is being done to produce drought-resisting plants for crops. What are the outstanding characteristics of such plants? Do you think man will ever be able to farm a large part of the desert regions?

4. In this chapter you find reference to the cactus, the Spanish bayonet (yucca), the Gila monster, the rattlesnake, and other plants and animals of the desert. See what you can find out about the life cycles of these. Use encyclopedias and prepare a class report on your findings.

5. Prepare a class paper on "Some Strange Animals That Live in the Desert."

CHAPTER ELEVEN

How Are Plants and Animals Adapted for Life in the Oceans?

THE OCEAN LIFE OF THE FRIGID ZONES

Land and Ocean Compared. In the last chapter we studied the driest places on earth. In this chapter we shall study the wettest. Even the soggy rain forests of the equator must take second place to the oceans for wetness. The ocean basins, indeed, are the only regions on earth which are thoroughly wet, and which have been so ever since they came into existence.

What do you know about life in these great bodies of water which cover more than half the surface of the earth? If you look at a map of the world, you will find that ocean water reaches in two unbroken bands from the cold regions of the north to the cold regions of the south. The narrower of these two bands joins the Arctic and Antarctic Oceans by way of the Atlantic. The broader joins the two polar oceans by way of the Pacific.

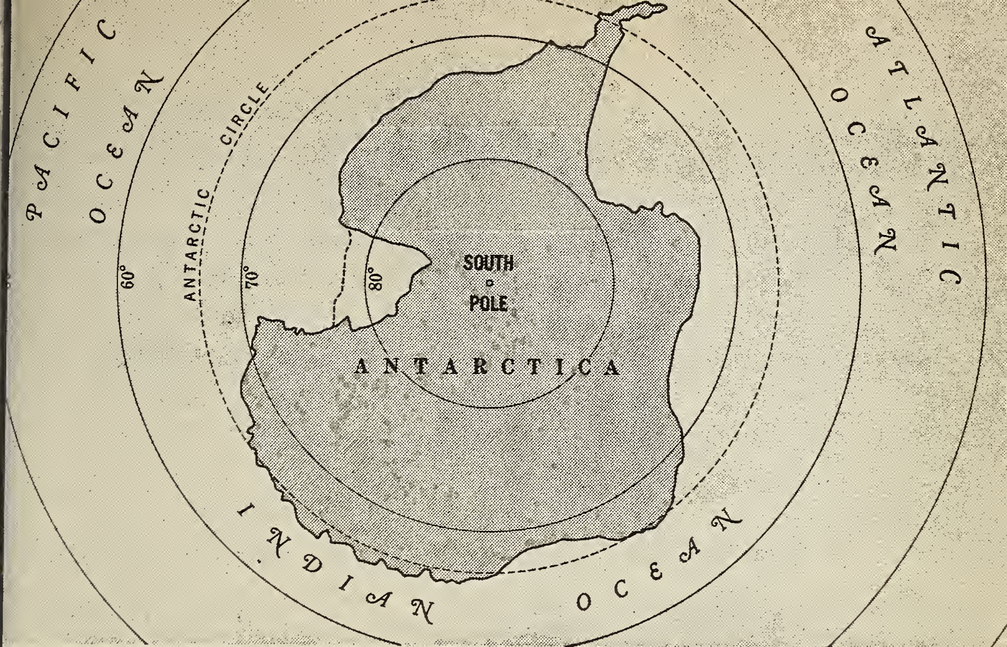
In the frigid zones the water of the oceans beats against polar ice caps during every month of the year. In the torrid zone the water of the oceans is always warm. Naturally these different conditions are matched by equally marked differences in the life along the ocean shores.

Marked as are the differences in the *waters* of the different zones, they are not so great as the differences in the *lands* of the different zones. Temperature, for example, varies much more from place to place on land than it does in the water. We have seen that Death Valley may get as

The north polar region is chiefly water

hot as 130° F. Northern Siberia, on the other hand, may get as cold as 90° below zero. This makes a range of two hundred and twenty degrees for the land temperature of the earth. In terms of comfort this range is great, but it is slight when compared with the temperature differences in the universe at large.

The oceans have an even narrower range of temperature from place to place than have the lands. The coldest ocean water is never below about 30° F., which is the freezing point of salt water. The warmest ocean water is seldom above 80° F. This makes a range of only fifty degrees for the ocean temperature of the earth, which is less than one fourth the range of temperature on the land. Ocean temperature is also less variable from time to time in the same place than is the temperature of the land. The change in the temperature of sea water from day to night and from summer to winter is very slight.



The south polar region is chiefly land

The Life of Land and Ocean Compared. The result of this greater evenness of temperature in the sea is that *there are fewer different kinds of living creatures there than on the land*. Conditions are pretty much the same over wide areas of the oceans, and the creatures that dwell there are also all pretty much the same.

This does not mean, of course, that the plants and animals of the oceans are all *exactly* the same. It only means that because there are fewer kinds of conditions in the oceans than on the lands, there are fewer kinds of adaptations among plants and animals. On the other hand, there are many more *individual* plants and animals in the oceans than on the lands. The sea is thickly inhabited, not only from north to south but also from the shore outward and from the surface downward.

So it is that if we study the living things in just one part of the ocean we shall not see very many different kinds of

adaptations. To see plants and animals living extremely different lives we must go to extremely different parts of the sea. We must go to the polar seas and compare the creatures that live there with those that live in the seas of temperate and tropical regions. We must compare the creatures of the shore with those of the surface water which is far from shore, and both of these with the creatures of the great depths. In this chapter we shall make these comparisons and see what we can learn.

The Arctic and Antarctic Regions Compared. Let us first study the life of the polar regions. If you look at the maps on pages 272 and 273, you will see that the area within the arctic circle is chiefly water and that within the antarctic circle is chiefly land. Because of the greater amount of land in the south polar region the climate is very cold—too cold, in fact, to support a great deal of land life. The only land animals that live on the great continent of Antarctica stay near the shore of the ocean and take their food from the water.

The north polar region, on the other hand, is chiefly water and for that reason is not so cold as Antarctica. During the long summer period of daylight vast areas of the Arctic Ocean are free from ice. Small swimming and floating animals are abundant in the open water, and many larger creatures live along the shore.

The Life of the Antarctic Region. One of the few visitors in the cold and barren land around the south pole is the penguin. This bird is unable to fly but is a powerful swimmer. It feeds upon fish and other sea life, but comes ashore to lay its eggs and to hatch its young. The penguin has absolutely no defense against enemies except running or

Popper from Monkmeyer

These baby penguins are sitting in the crude stone nest where they were born

swimming away. Fortunately it nests in regions where there are no land animals to harm it or to eat the eggs and destroy the young. No other animal is adapted to live through such hard conditions as those which this strange bird thrives on. A family of penguins is pictured on page 275.

They nest in the darkness of the antarctic winter, with the temperature often as low as sixty degrees below zero. The young are helpless when hatched and must be cared for by their parents. By late summer (January in the Antarctic) the young are able to swim and to hunt for food. They then make for the open ocean and remain there until they are ready to breed.

Exercise. Find out all you can about penguins and make a report on them for your class.

The waters north of Antarctica, like the waters of the Arctic, are rich in plant and animal life. Some large water animals, including seals and whales, feed there. But there are no regular human inhabitants anywhere south of the antarctic circle. Compared with this region, the region north of the arctic circle—where more than a million people live—is a thickly inhabited country.

The walrus is one of the largest animals of the North
H. Armstrong Roberts

The Life of the Arctic Region. In the more friendly Arctic there are many land animals, large and small, but

Three Lions

ese seals have come to breed on one of the Pribilof Islands off the coast of Alaska. Notice the large "bulls," the smaller "cows," and the still smaller "pups"

most of them depend directly or indirectly upon the life of the sea. Walruses, seals, and polar bears live in large numbers along the seashores of the north frigid zone.

The walrus is a very large animal and could not possibly get along where food was scarce. Some walruses weigh as much as a ton each (see page 276). They live in herds of from thirty-five to fifty individuals, and feed upon shellfish that are plentiful in the mud along the coast. Their large tusks are well adapted for digging their food. Walruses are valuable for oil, hide, and ivory. Their numbers have been greatly reduced during recent years by hunters.

Seals have always been very numerous along arctic shores. These graceful animals are powerful swimmers. They feed upon fish, shellfish, and sea birds, and in turn are fed upon by polar bears and Eskimos. They are beauti-

fully adapted for life in the Far North. A thick layer of fat just beneath their skin protects them against the cold. They are able to catch all the food they need, and when not disturbed they develop into enormous herds. A large herd of seals is shown on page 277.

The abundance of sea life in northern waters makes the Arctic a favorite feeding ground for the biggest of all animals, the whale. The largest whales may weigh nearly one hundred and fifty tons, four times as much as the largest dinosaurs of past ages! Oddly enough, these largest of all living animals in some cases eat the smallest kind of food.

The whalebone whales live on small plants and animals which they catch as they swim along with their mouths open at the surface of the water. With the help of a special sieve-like organ they are able quite easily to gather great quantities of food. As much as two tons of small sea life has been found in the stomach of a single individual. Other whales live on larger animals.

The whales are powerful swimmers and great travelers. They spend the summer in the polar regions, and then migrate with the coming of winter almost as far as the equator. The whaling industry has greatly reduced the number of whales, and some kinds once numerous are now extremely rare. There are more whales at present in the Southern Hemisphere than anywhere else, and whale-hunters are most active during the summers in the Antarctic.

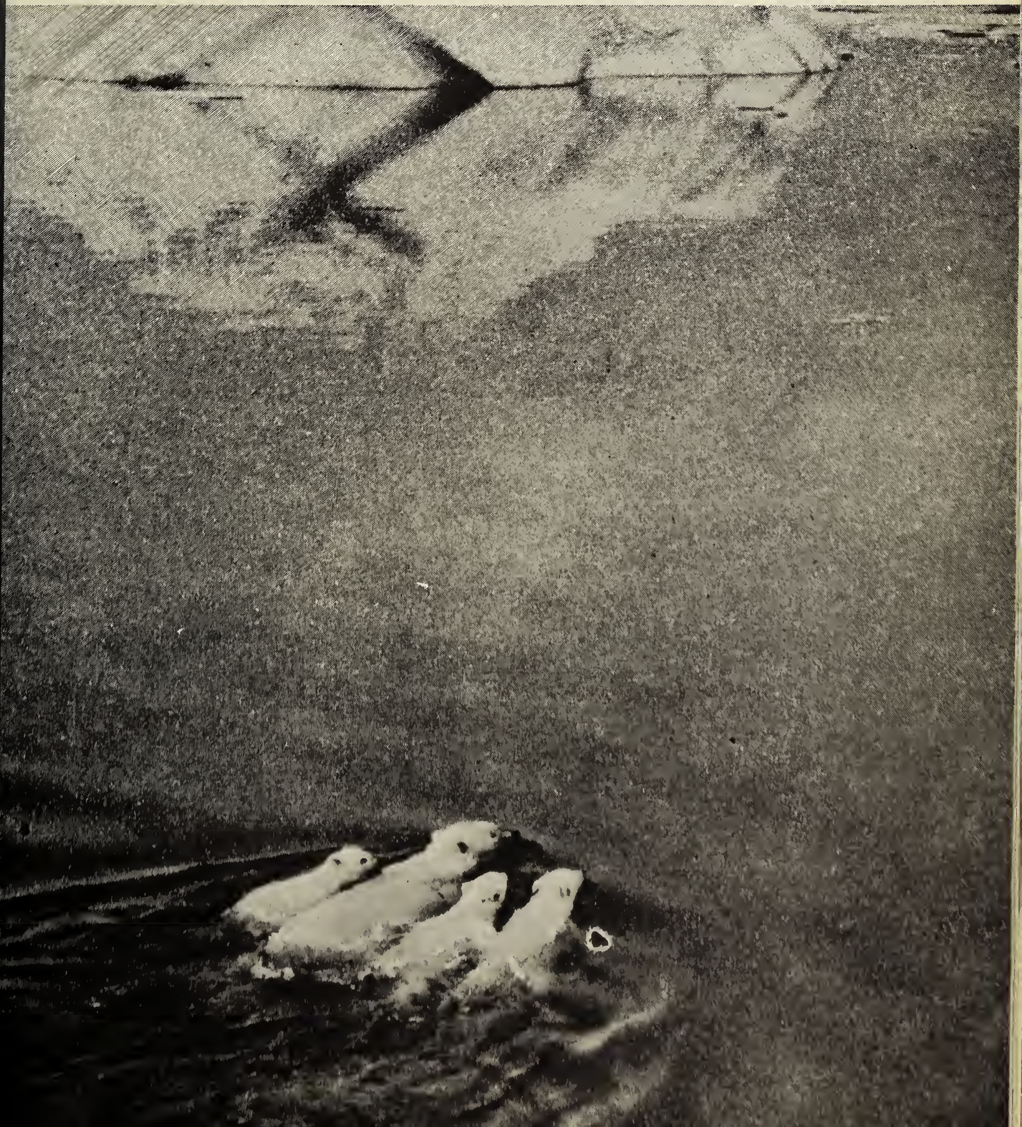
Exercise. Look up and make a report on the whaling industry. Is it the same today as it was a hundred years ago?

The polar bear is a familiar animal of the Arctic. It feeds mostly upon animals that live along the shore, but,

like the whale and other animals, its food comes indirectly from the green plants. The polar bear feeds on seals; seals feed largely upon fish; fish feed upon a variety of smaller animals that float and swim in the sea; these smaller creatures live largely on tiny green floating plants. So in the cold regions of the earth, as everywhere else, the green plants make the foundation for the house of life.

Family life goes on in the Arctic too

Three Lions



THE OCEAN LIFE OF THE TEMPERATE ZONES

Rocky Shores in the Temperate Zones. Away from the frigid zones, in regions where the oceans are practically free from ice throughout the year, most living creatures of the sea make their homes. A great many of them never wander far from shore. If you should take a walk along the coast in the north temperate zone, you would soon discover that the seashore is not a barren stretch of rock and sand. You would need to be only a little observing to find it a place where many interesting plants and animals live.

Let us imagine that you are walking along a rocky seashore. The first things to attract your attention would very likely be the barnacles and rockweeds. Barnacles are small sea animals which cover the rocks with their white cone-shaped shells. Rockweeds cling to the rocks in thick clumps. Both of these types of living things are shown in the illustration on the opposite page.

The rockweeds are especially interesting because they provide a home for many small animals such as periwinkles and crabs. In addition to these, several kinds of seaweeds, sea anemones, barnacles, crabs, and snails live in the cracks and crevices of the rocks. Just above the low-tide mark along some rocky coasts, black mussel shells may be so numerous that they cover the entire surface of the shore.

Exercise. If you live near the seashore, go there at low tide and make a collection of as many different rocky-shore creatures as you can find. Prepare a salt-water aquarium with the help of your teacher and try to keep your specimens alive. If you live away from the shore, make a collection of pictures showing rocky-shore plants and animals. Explain how each one is adapted for the life it lives.

How many of these rocky-shore creatures do you know?

Sandy Shores in the Temperate Zones. On sandy shores in the temperate zones most of the inhabitants live beneath the surface. You can find them only by digging in the sand. They may expose their hiding places, however, by the open mouths of their burrows or by the jets of water or bubbles of air which they send up.

Many kinds of clams and snails, as well as some crabs, live in this manner. There are also the strange round flat shells called sand dollars which lie buried just below the surface of the sand at the low-water mark. Then, too, sandy shores may be full of the burrows of sand hoppers, which jump along the beach as do grasshoppers in the fields. Egg cases of many odd shapes and belonging to many different kinds of animals may also be found along sandy beaches where they have been washed up by the waves. (See the opposite page.)

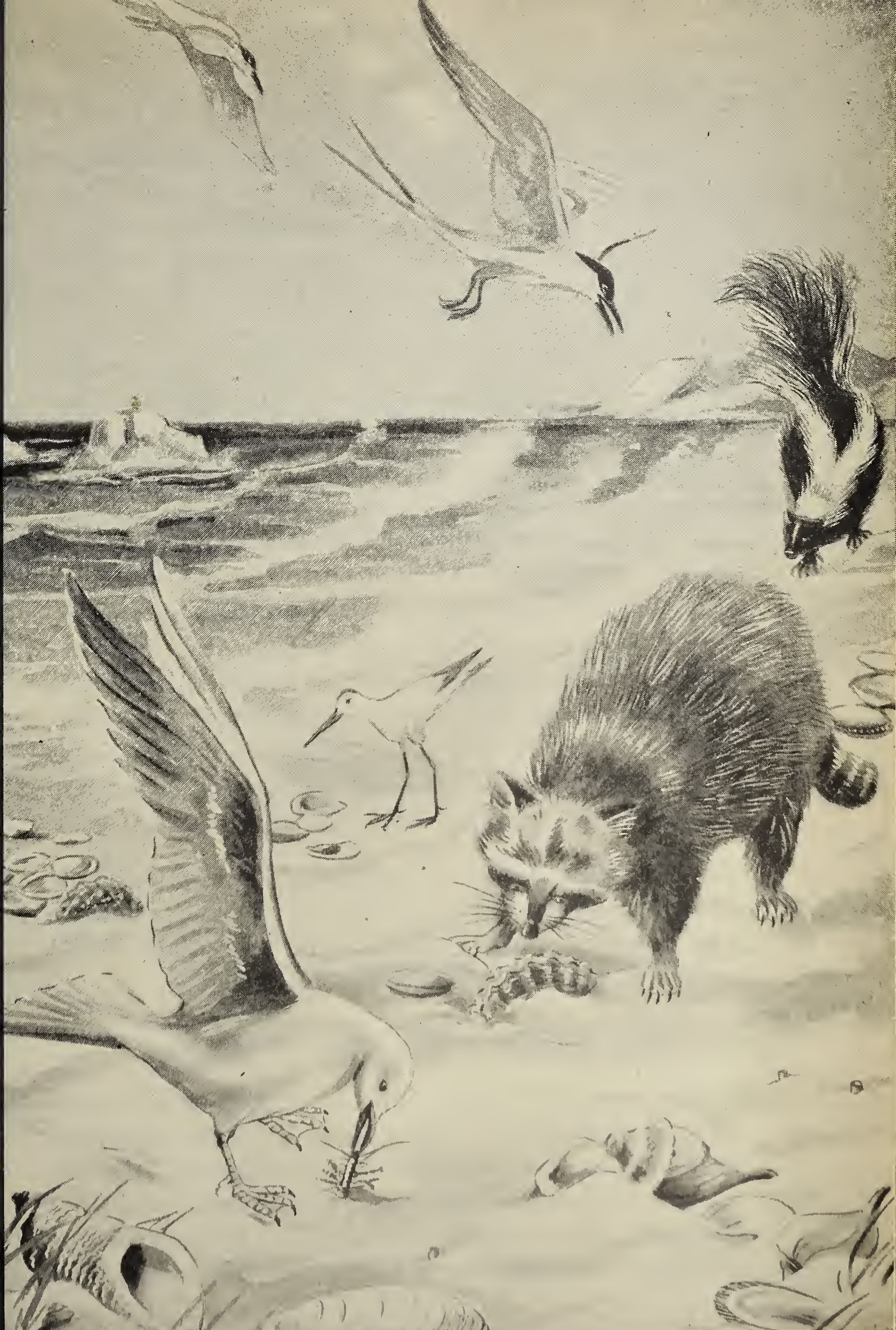
Exercise. Make a collection of specimens or pictures of the plants and animals of sandy shores, as you did for those of rocky shores.

Muddy Shores in the Temperate Zones. On muddy shores the eelgrass often grows abundantly, giving the appearance of a flooded meadow. Many animals live upon or in the midst of this grass. Scallops and prawns are very common. Clams, crabs, and worms are also plentiful in such regions. The common crab, the fiddler crab, the hermit crab, and the spider crab are all dwellers on muddy seashores. (See page 284.)

Exercise. Make a collection of specimens or pictures of muddy-shore life, as you did for the life of rocky and sandy shores.

How many of these sandy-shore creatures do you know?

How many of these muddy-shore creatures do you know?



When the tide is out it is dinnertime for many creatures

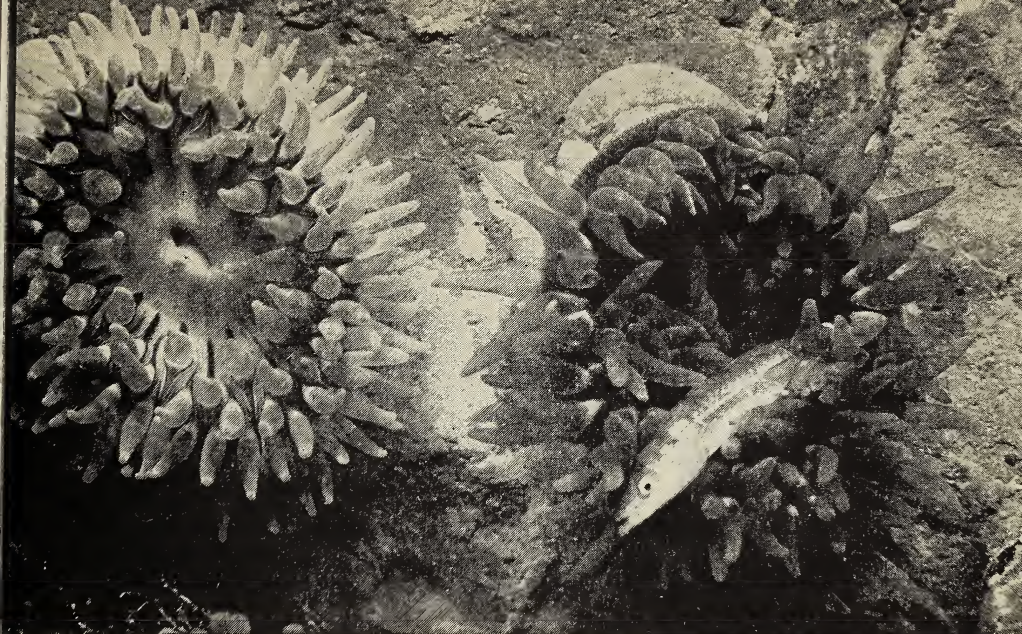
Adaptation to the Tides. All the plants and animals of the seashore are adapted to the daily rise and fall of the tides. Those of rocky shores are rather generally strengthened with shells against the beat of the waves, and with sucker-like attachments for clinging to the rocks when the sea is swishing around them. Those of sandy and muddy shores are rather generally protected from the pounding surf by the habit of living in burrows. In addition to this, many creatures of the seashore are adapted to live equally well in the air when the tide is out and in the water when the tide is in.

When the tide is out, a great many living things are exposed to the air which are covered with water when the tide is in. Many land animals take advantage of this fact. Notice the birds in the drawing on page 285. They are feeding on sea creatures that are stranded on the beach at low tide. Gulls, terns, sandpipers, and many other birds are shore feeders of this type. Certain four-footed animals —raccoons, minks, skunks, and many others—are also adapted for living on food which the tide uncovers.

Exercise. Many forms of seashore life in the temperate zones have interesting life histories. Look up and make a report on some of the common forms. The hermit crab would make a very interesting beginning.

THE OCEAN LIFE OF THE TORRID ZONE

The Beauty of Tropical Seas. In all the climate zones there is an abundance of sea life in the water which lies near the shore. It is probably most abundant, however, along the shores of tropical seas. The picture on page 289 illustrates some of the kinds of life to be found in the Caribbean Sea. The ocean bed in the shallow waters of



F. Schensky, Helgoland

hough rooted to the ground like a plant, the sea anemone is really an animal with tentacles for catching its prey as it swims by

such a sea may look like a flower garden with purple, red, orange, violet, and green colors all blended in one shining mass. Yet there is not a single flower, not even, as a rule, a single seaweed in the entire picture!

Sea Anemones. The things that look like cacti, dahlias, and fringed chrysanthemums are really animals which are known as sea anemones. A sea anemone when young attaches itself to a rock or a shell upon the bottom in shallow water. Its body is a hollow tube that acts like a stomach. The upper end, as shown above, is a mouth surrounded by rows of moving fingerlike growths called tentacles.

These animals are especially well adapted to their environment. They are fastened to the rocks and cannot move about in search of food. But they get plenty of food without moving about. They merely sit still and wait for their food to come to them. Tropical waters are rich in a

variety of small animals; and when these swim by, the sea anemones grab them with their tentacles.

Corals and Sponges. Other very common forms of life which live attached to the bottom in tropical waters are the corals. Brown, green, yellow, and violet in color, corals may branch upward for many feet, like stony cactus plants. The hard material which gives a coral growth its shape is limestone. It is discharged from the bodies of many little animals which look like tiny sea anemones. The limestone structure is built from minerals taken out of the sea water and it serves as an apartment house for the thousands of tiny animals that build it. As new individual corals are born, each one builds its home on top of that of its parent. In this manner coral reefs, such as the one pictured at the foot of the opposite page, are formed.

Coral reefs make homes for many other living things. In an ordinary coral reef there are many sea plants which, like corals, have skeletons of limestone. These strange plants grow into tight masses of rock and help build up the reef. The nooks and crannies of coral reefs make fine sheltered homes for almost every imaginable kind of salt-water creature.

Exercise. Prepare a report on "Exploring a Coral Reef." Read Beebe's *Beneath Tropic Seas*, a fascinating record of diving among the coral reefs of Haiti.

Sponges are familiar animals of the tropical seas. The common types whose skeletons we use for washing and cleaning are most familiar, but there are many other kinds. Some sponges form thin, lacy, fernlike structures which sway to and fro with the gentle motion of the water. Others look much like the corals. All of them, however, feed in

Buffalo Museum of Science

Tropical sea bottoms may look like gardens, but most of the "flowers" are animals

The "bushes" on this reef are made of stone which was secreted in the bodies of many little coral animals

W. Saville-Kent

the same way. The water, with its wealth of very tiny plants and animals, flows through the holes of the sponge. Cells located within these holes take some of this food material as well as oxygen from the water. Certain giant sponges weigh more than a hundred and fifty pounds after all the water has been evaporated from them.

Sponges, like corals, give shelter to many other living things. A sponge cut into pieces by a group of trained observers was found to house one shrimp for every cubic inch—and several small crabs thrown in for good measure. In the hollow center of the sponge many tiny fish had lived, and had crawled about on their fins through the tunnels in the walls.

The Larger Animals of Tropic Seas. In the tropics, as in the frigid zones, there are many large animals that live in and around the ocean. Sharks are lovers of warm water. Though many kinds wander into the oceans of the temperate zones, most stay within the tropics. The great white shark (the "man-eater") may reach a length of forty feet. He is as vicious as he is large. If we are to believe the stories that are told of him, he enjoys an occasional meal of man to vary his diet of fish.

One of the most interesting creatures on earth is the bird which is known as the

Sponges thrive in the warm water of tropical seas
Fenimore-Johnson Laboratories

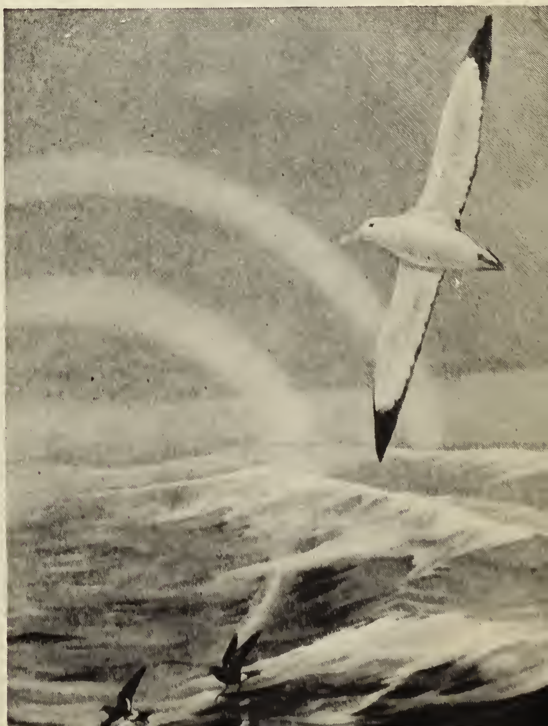
albatross (see below). Most albatrosses live in the tropics, though some of them wander as far north as Alaska. Some of these birds have a wing spread of twelve feet and are the largest flying animals in the world. Superstitions cluster round them, as those of you who have read "The Ancient Mariner" will remember. Many sailors believe that the albatross can stay in the air without moving its wings, and can follow a fast-moving ship as if by magic.

Careful observers, however, have noticed that the wings of the albatross do actually move in short, quick jerks. These movements are practically invisible unless the bird is on a level with the eye of the observer. With its great wing surface the albatross uses the currents of air for soaring, and is one of the mightiest aviators on earth. These birds range far and wide over the ocean and come to land only to lay their eggs. They are beautifully fitted for the lives they lead.

LIFE IN THE OCEANS AWAY FROM THE SHORE

The Strange Sargasso Sea. Not all the plants and animals of the sea cling to the shores. East of the West Indies but west of the Azores, in the middle of the Atlantic Ocean, lies a stretch of calm water known as the Sargasso Sea.

The large white bird is the mighty wandering albatross[1]



[1]From full color painting by F. L. Jaques in *Oceanic Birds of South America*, by Robert C. Murphy, published by the American Museum of Natural History.

Here is a wilderness of floating seaweed, about which sailors in past ages have told strange tales. Here, according to accounts, was the home of terrible monsters and a graveyard for the floating wrecks of many ships. Into these waters, too, good ships loaded with men and cargo were supposed to have been drawn, and to have been spun like tops in a never-ending whirlpool. The heavy seaweed, it was said, made escape impossible. Needless to say, these stories were proved false as soon as scientists made careful studies of the region.

The seaweed in the Sargasso Sea was not brought in from distant shores, as was once believed. It came into being where it is now found, and is held in this location by ocean currents. The Sargasso Sea is a region of nearly still water about half as large as the United States. It lies between the Gulf Stream, which flows toward the northeast, and

The Sargasso Sea is a slow whirlpool made by currents in the Atlantic Ocean

Buffalo Museum of Science

This is a "fisheye" view of the Sargasso Sea

other ocean currents which flow toward the south and west. The map on the opposite page will show you the Sargasso Sea with reference to the ocean currents which have brought it into existence.

No strong currents flow outward from this region. As a result, any seaweed that floats into it is likely to remain. Seaweed actually covers only about 10 per cent of the surface of the Sargasso Sea. William Beebe and other scientists have explored the region thoroughly and have studied the plants and animals that live there. With all their observations they never saw a sea serpent or an abandoned ship!

Life in the Sargasso Sea is even more plentiful than in the warm waters of the Caribbean, because the masses of seaweed (sargassum) offer both food and protection to many creatures. There are a great many kinds of fishes,

including sharks, flying fish, eels, and sea horses. There are jellyfishes in great variety, octopuses, and many other strange animals. The weed itself is held up by numerous small air bladders that grow upon its tips. As it grows it becomes covered with the shells and skeletons of animals, which make it heavier and heavier until finally it sinks to the bottom.

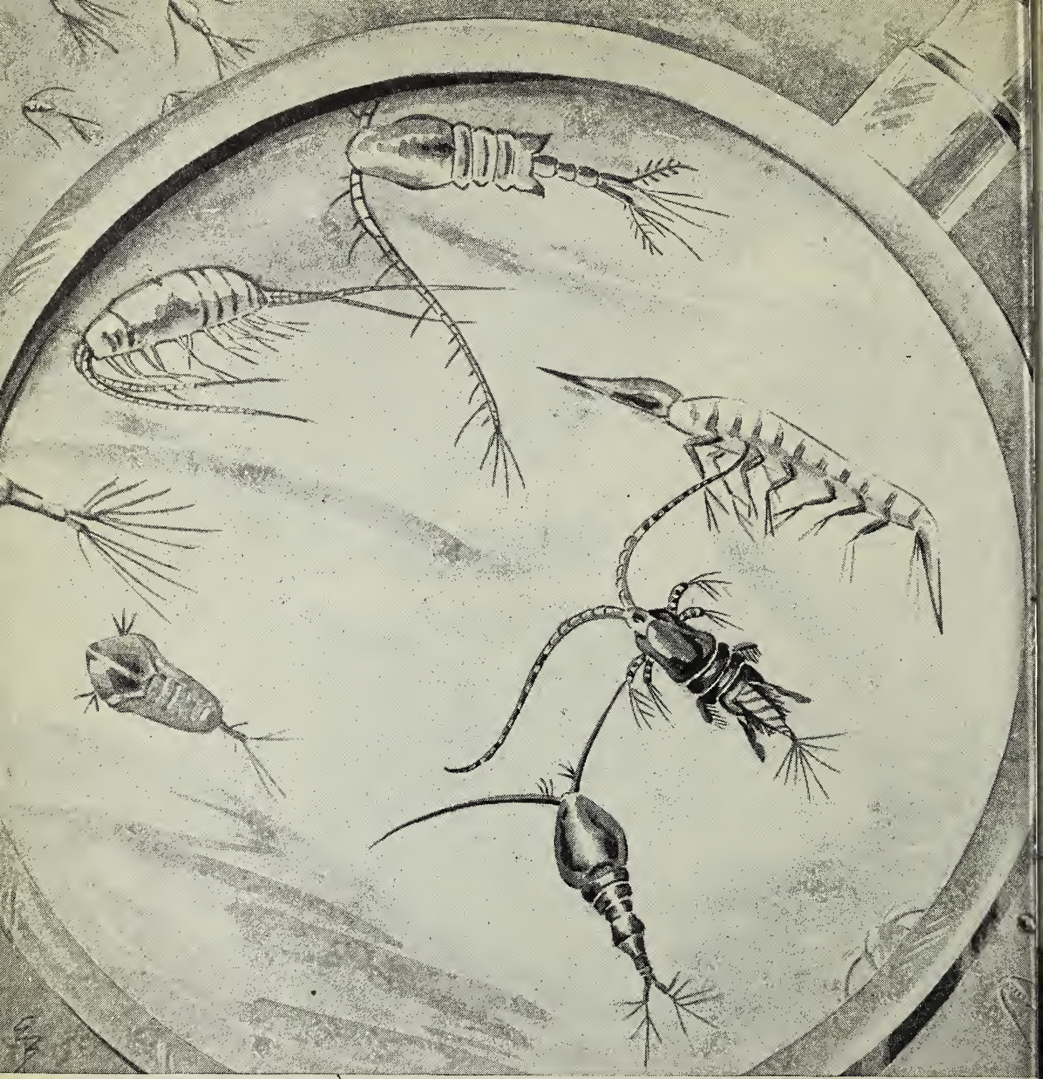
The Mystery of the Eels. One of the most curious recent discoveries in science has to do with the life history of the common eel. For years boys used to catching eels on their fishlines have wondered why they never caught any young ones. Scientists, on the other hand, have been puzzled to find eels which were exactly alike in both fresh and salt water. The same kind of eel lives in the ocean and in landlocked lakes and ponds as far as two hundred miles inland. How does the same kind of eel manage to live in both places?

The mystery was solved when scientists who were collecting specimens in the Sargasso Sea found eels breeding in the deep waters there, two thousand miles from land. The tiny young eels were so unlike their parents that they had not before been recognized as eels. It was further learned that the young eels somehow find their way to the mouths of fresh-water streams, in both Europe and America. They swim up the rivers and live in fresh water until they are mature.

The adult eel lives in its new environment for many years. Finally it starts back to its birthplace far out in the Sargasso Sea. There it lays its eggs and then dies. The eggs hatch, young eels develop, and the same life cycle begins all over again. How do eels find their way from the Sargasso Sea to the fresh waters of two continents and then

F. Schensky, Helgoland

This large jellyfish is one of the sea's most handsome citizens



The pygmies of the sea

back to the Sargasso Sea? This part of the mystery has not been—and probably never will be—solved.

The Pygmies of the Sea. The abundance of tiny living things at the surface of the sea has already been mentioned. Many of these are visible only through a microscope. Many are green plants which grow and manufacture food just as land plants do. The plants are most numerous in the spring,

and along with their development come many forms of small animals to feed upon them (see the opposite page). These tiny living things, both plants and animals, furnish food for larger animals, and these in turn for still larger ones.

Fishes of the Open Ocean. Among the larger animals of the open ocean fishes are the most abundant. In the north Atlantic the herring is perhaps the most common fish. Herring travel in schools, or shoals. A single school may cover as many as four or five square miles and may contain as many as two or three billion fish. Mackerel are somewhat larger than herring. They also travel in schools, in which the number of individuals may run well up into millions. In addition to these there are salmon, codfish, and many others. The average annual catch of salmon alone is more than a billion pounds. A haul of salmon taken from Pacific coast waters is shown in the illustration below.

Salmon is one of the sea's most valuable crops

Ewing Galloway

Exercise. On an outline map of the world mark the location of the chief fishing centers. If possible, get figures concerning the number of people employed in each center and the value of the fish caught.

Life beneath the Surface of the Sea. The food of these fishes has its origin in the tiny green plants that live at the surface of the sea. No green plants can live at a greater depth than a few hundred feet. *Life beneath the surface depends upon food that sinks to it from above.* Animals living beneath the surface catch food as it slowly sinks toward the bottom. In the depths the animal life is distributed in zones. Fish adapted to live at a thousand feet cannot live at ten thousand feet. The pressure of the water and the character of the food at the various levels force them to stay within their own zones.

If you could picture the food that sinks beneath the surface of the sea, you would see a large number of dead animals on their way toward the bottom. Live animals are waiting below to eat them as they sink. Wherever there is food, there are animals to eat it. Strange creatures like those pictured on the opposite page have been brought up by dredges from depths greater than twenty thousand feet. At still greater depths the food supply grows less, and so too do the creatures that eat it.

The strange-looking inhabitants of the deep are adapted to live in a strange environment. Some can make light as the firefly does on a summer evening. Possibly this light helps them to catch their food as it sinks through the darkness. It is the smallest particles of food that are used first, because the smallest pieces sink the slowest and are the easiest to catch. The food at great depths is likely to be in large chunks. The immense mouths of many

deep-sea fishes (in some cases larger than all the rest of the body) are probably adaptations for catching these large chunks.

At great depths in the sea it is always night. The temperature, only a few degrees above freezing, remains the same year in and year out. Yet, strange as it may seem, there are many living things adapted to these conditions and quite unable to live under any other.

We have now come to the end of a very rapid survey of the plants and animals of the oceans. We have seen that in the sea, as on the land, living things vary with the climate. We have also seen that in the sea the environment changes both with distance from the shore and with depth below the surface. Lastly we have seen that the boundaries between the different zones in the sea are less sharp than similar boundaries on land. Adaptations for different ways of living, though they exist in the sea, are accordingly not so sharply marked off from one another as are the adaptations of creatures that live on the lands.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Temperature varies much more from place to place in the sea than it does on the land.

2. There are more different kinds of living things in the sea than on the land.

3. The region around the north pole is the coldest portion of the earth's surface.

4. The penguin is a powerful flier and can be seen throughout the north frigid zone.

5. The polar bear is the only large animal that lives on the continent of Antarctica.

6. The seashores of the temperate zones are almost entirely lacking in plant and animal life, though barnacles are fairly common on sandy beaches.

7. The sea anemone is perhaps the most beautiful plant of the ocean.

8. Coral reefs are formed when the stony skeletons of dead corals are heaped in ridges on the ocean floor by waves.

9. The albatross is the only bird that can fly without moving its wings.

10. The Sargasso Sea is a vast region in the Pacific Ocean which is entirely filled with seaweed.

11. It has recently been learned that eels live in the ocean but, like salmon, come up into fresh water to breed.

12. The fishes that live in the darkness of the deep ocean, where green plants are absent, must depend wholly on one another for food.

Questions for Discussion

1. For a long time most polar explorations went to the north polar regions. Can you think of any reasons why?

2. What living things in the ocean experience the least change in physical conditions throughout the year?

3. How do you think the stories of sea serpents start? Do you think there is any truth in them? What form of life do you think these so-called sea serpents might be?

Things to Do

1. There are many books on polar explorations. The latest are by Rear Admiral Byrd. Some men before him, however, made attempts to reach both poles. Their books

will tell you a great deal about conditions in the polar regions. See if your library has the works of Rear Admiral Peary, who discovered the north pole. Amundsen, a Norwegian, was the first to reach the south pole. His story too is in book form. Then there was Captain Scott, an Englishman, who after terrific struggles also reached the south pole, only to find that Amundsen had been there a few months ahead of him.

2. Do you know how important a part the fishing industry plays in supplying the food for the United States? See what figures you can find on the fishing industry, and prepare a class report about it.

3. Read William Crowder's *Dwellers of the Sea and Shore*. This is a very interesting book written for young people about the life in the sea near the author's Long Island home. Henry Beston's *The Outermost House* is another interesting book which deals with life on a Cape Cod beach.

4. If you live near the ocean, make a collection of sea shells. Use R. W. Miner's *Field Book of Seashore Life* to help you identify your specimens.

5. Read *Moby Dick*, by Herman Melville, the most famous story of whaling ever written.

CHAPTER TWELVE

How Is Man Adapted for the Life He Leads?

MAN'S ADAPTATION TO HEAT AND COLD

The Varied Life of Man. So far in this unit we have studied how plants and animals meet the changes of an ever-changing world. How does man meet these changes? How is he adapted for the life he leads? To answer these questions let us first try to learn just what kind of life he does lead.

If you should go to the high plateau of Tibet in central Asia, you would find men living there, three miles above the level of the sea. If you should go to the Imperial Valley in southern California, you would find men living there, two hundred feet below the level of the sea. In the same way, you would find men living in the sizzling heat of Java, in the bitter cold of Lapland, in the Sahara with a rainfall of less than five inches a year, and in Malay with a rainfall of more than two hundred inches a year.

If you went to Butte, Montana, you would find men working in mines some thousands of feet below the surface of the earth. Almost any day you can lift your eyes to the sky and see men-driven airplanes some thousands of feet above the surface of the earth. If you stood for an hour in a great railway station, you would see men who have come there from almost every corner of the earth. If you went to the harbor of a great coastal city, you would see ships which carry men and their goods all over the world.

What does all this mean? It means that man has made practically the whole earth his home. It means that *man is the most widely adapted living thing* in the world. Where is there a wild creature that lives in as many different places and under as many different conditions? The answer, of course, is Nowhere. But how can we explain man's ability to live so varied a life?

The Intelligence of Man. We can explain it largely through man's big and complex brain. Animals pretty generally have to live in the world as they find it. With the help of his powerful brain man can change his surroundings to suit his needs. The result is that man can live almost anywhere he chooses—and he chooses to live almost everywhere.

He can live, for example, under the extremes of both heat and cold. If it were not for his large brain and the intelligence which his large brain gives him, he would die in such unfriendly places. Instead, through careful study and planning he can live fairly comfortably in the cold and dark of the polar winter. He can live healthfully in the heat and rain of the equatorial summer. (See opposite page.)

Natural Adaptations. Most animals are adapted to special environments. A fish, for example, that found itself on a mountaintop would soon die because it cannot breathe in the air. An eagle, on the other hand, would soon die at the bottom of a lake because it cannot breathe in the water. These and all other animals are *naturally* fitted or adapted for their own special ways of life, and they know no means of changing or adding to these adaptations. If their environments change very noticeably, they can only die.

Artificial Adaptations. Man is like the animals in being naturally adapted to certain conditions and ways of life.

Wide World

The headquarters of Admiral Byrd in Antarctica are an adaptation to extreme cold

These buildings in the Canal Zone are an adaptation to extreme heat

But he is unlike the animals in that he can extend the range of his adaptations *artificially*. Like the eagle, for example, he cannot naturally live beneath the water. Unlike the eagle he can invent a diver's helmet and explore the bottom of the sea in comfort and safety. In countless ways man has used his power of invention to extend his adaptations. Through such artificial adaptations he has made himself the freest living creature on earth.

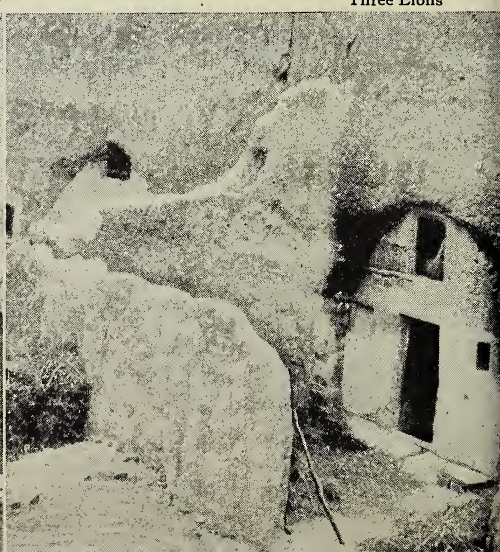
The House. Though man does not have the fur of the polar bear, he lives comfortably in the polar bear's country. Though he would die of sunstroke under long exposure to the tropical sun, he lives in the tropics in spite of the sun. The swirling sands of the desert and the snows of winter in the temperate zone are both unfriendly to him, yet he lives with them in comfort and health. He does all this to a large extent through the artificial adaptation of the house.

Inside his house, and in some cases with the help of fire (another artificial adaptation), man can defy any kind of weather and climate. *Inside his house he makes his own weather and climate to suit his needs.* Through the artificial

The Indian tepee of the American prairie and the Chinese cave home of the Yellow River valley are both artificial human adaptations

Galloway

Three Lions



Galloway Swiss Federal Railroads

n very different kinds of houses men meet the challenge of very different kinds of climate

shelter of houses, men are able to live under more different kinds of conditions than any other creatures on earth. We need only look at the different kinds of houses used by man to realize how different these conditions are (see photographs on opposite page and above).

How Man Is Naturally Protected against Change in Temperature. Man's adaptations to changes in weather and to differences in climate are not entirely artificial. We have already seen that the body of a person in good health always remains at about the same temperature. This temperature may be measured in the mouth and in most healthy people is never very far from 98.6° F.

By a wonderful system of heat regulation within our bodies, the food we eat is turned into just the right amount of heat to keep our temperature constant. When it is cold and we exercise a great deal, our bodies need more food in order to maintain their normal temperature. Hunger gives us the signal, we eat more food, and our bodies do the rest. No matter how cold the air around us may become, we do not get much cooler than 98.6° F. so long as we are in good health. During extreme cold, however, the body may fail to maintain its normal temperature. When this happens

to a person, he must be transferred quickly to a warmer place or else he will freeze to death.

If the air around us is very warm or if we exercise with vigor, perspiration increases. Our bodies would get warmer under these conditions if it were not for the perspiration. This evaporates from our skin and in doing so carries heat from us to the air. Do you see, then, that under all changes of weather, climate, and activity, we have within us firemen that keep our boilers burning with a steady heat? It is generally only when we are ill that the temperature of our bodies goes much above or below 98.6° F.

Exercise. How to prove that the temperature of our bodies does not change with the temperature of the air around us: Go to the warmest place you can find and take your temperature with a clinical thermometer. Then go to the coldest place you can find and do the same. Be sure to place the end of the thermometer well under your tongue and leave it there for two minutes before reading it. Does the temperature of your body change with the temperature of the air around it?

How Man Protects Himself Artificially against Changes in Temperature. Though nature has provided very well for man in a world of changing temperature, man has used his intelligence to improve on nature. He has added to the natural heat-regulators within his body the artificial heat-regulators which he calls clothes. When winter comes we put on heavier clothes to help keep our body heat from leaking away. In summer we put on lighter clothes to help keep our bodies cool. Look at the different types of clothing in the photographs on the opposite page. Do you see how they represent different types of artificial adaptation to different environments?

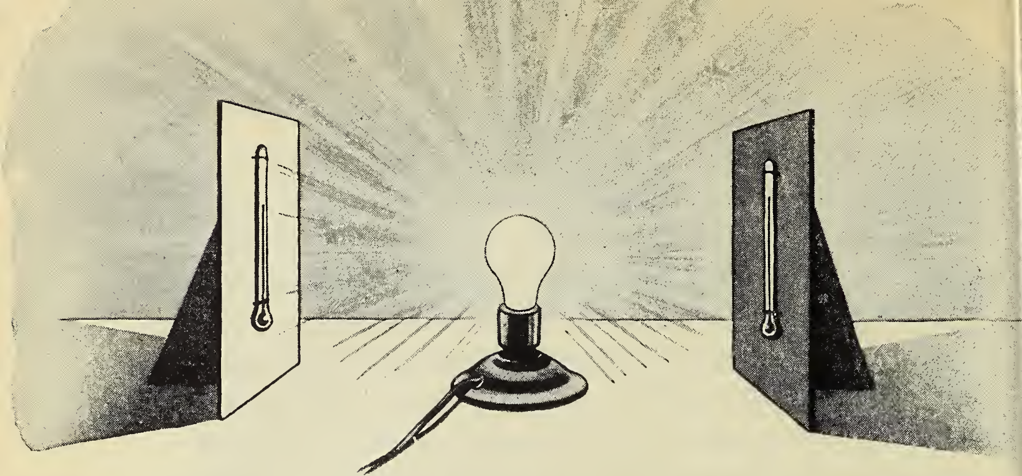
Wool is the best material to protect us against cold because it is the poorest conductor of heat. It acts as a wall around our bodies through which our warmth cannot easily pass. Linen is the best conductor of heat. It acts as a sieve through which our body warmth can easily pass.

Have you ever noticed that winter clothing is generally fairly dark-colored and summer clothing fairly light-colored? Perhaps you think this merely a matter of style but there is a better reason for it. *Dark clothing absorbs heat while light clothing reflects it.* It is therefore sensible to use dark clothing in winter to help keep us warm and light clothing in summer to help keep us cool.

Exercise. How to prove that dark objects absorb more heat than light objects: Set up two thermometers on pieces of white and black cardboard, as shown on page 310. Fasten the cardboards, two feet apart in an upright position, to a table, and place an electric-light globe halfway between. Turn on the light and watch the thermometers. Does the black or the white cardboard absorb more heat?

Man's use of clothing varies with the climate

Ewing Galloway



How to prove that dark objects absorb more heat than do light objects

MAN'S ADAPTATION TO DISEASE

The Health Problem of Civilized Man. There is an old saying that "you cannot get something for nothing" and it seems to apply particularly to health. Men have exchanged the hardships of the field and forest for the comforts of the house. They do not expose themselves night and day to the beat of the weather, as animals do. Each year new inventions bring new comforts and ease of living and carry men farther away from the strenuous outdoor lives which the animals lead.

These inventions that bring comfort may at the same time bring ill health if we are unintelligent in the use of them. Vigorous physical exertion in the open air is one of the best methods of maintaining our health. Millions of men have exchanged outdoor exertion of their bodies for indoor exertion of their minds. Their adaptations to certain diseases, as a result, are not so effective as those of the wild animals of forest and field.

One of the greatest problems of civilization is the control of health. To be sure, men have used their intelligence to reduce many of the diseases which attack civilized com-

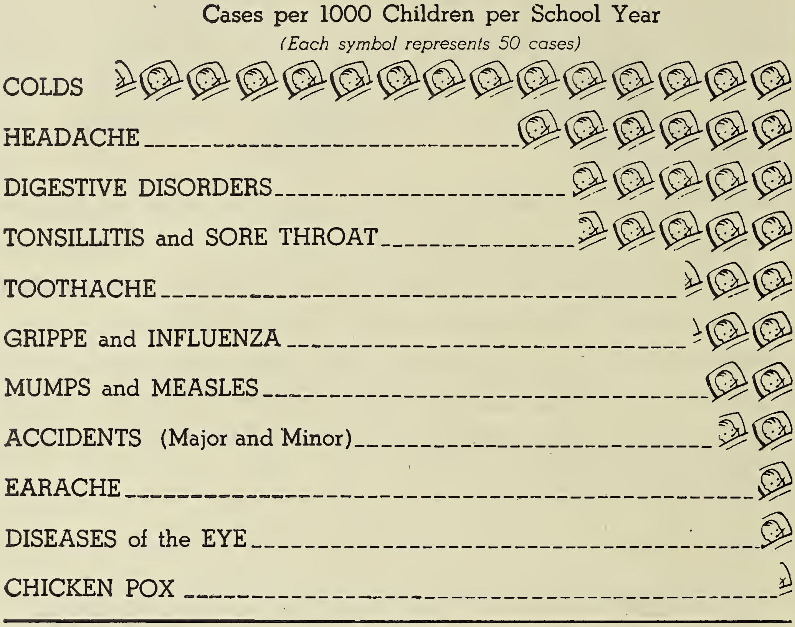
munities. But the problems of health are not all solved. Not only that, but they probably will never be solved until men generally are willing to put less faith in pills and more faith in the simple habits of a natural life. How can we best combine our artificial and our natural defenses against the diseases that attack us? Let us see if we can find out.

The Need of Sunshine. All through the study of science we shall find that the sun is the giver of life, health, and activity on earth. When men took to living in houses they turned their backs on the sun. In the temperate zones, where winters are generally cold, long, and dark, most people absorb less sunlight than their bodies need. Unless they plan to spend an hour or so in the air each day, they are likely to suffer.

Outdoor play in winter is one of the best ways of preserving health

H. Armstrong Roberts

Diseases and Disorders among School Children in Hagerstown, Maryland



Sunlight is especially necessary for the health of children because it is sunlight that helps build the calcium of their food into good strong bones. Where winters are so severe that children cannot get enough sunshine, cod-liver oil should be added to the diet. This will take the place of sunlight to a certain extent. On the other hand, there are many good days for outdoor play in winter, and children should make the most of them.

The Common Cold. Indoor living lowers the natural resistance of the body to disease, and the common cold is part of the price we pay for the comforts of the house. *As a cause of illness among school children the common cold leads all other diseases.* Above is a graph made on the basis of figures secured through a study of school children

Here are some of the best ways of preventing colds

over a four-year period in an Eastern city. Notice that for every thousand children there were over seven hundred cases of colds every year.

The nature of this most common of all ailments is poorly known. Millions of dollars are spent every year on cold remedies, but there is no proof that any of them do much good. One physician has wisely said that with medicine a cold will get well in about two weeks and without medicine

it will last about fourteen days. The best treatment for a cold is plenty of sleep, rest, and warmth.

Far better than treatment is prevention. Colds probably cause more discomfort to the human race than all other illnesses combined. People, to be sure, are not all equally given to colds. Some have them often and others rarely, but nobody entirely escapes them. Most persons could have fewer colds than they do if they took proper precautions against them. *The very best way to build up resistance against colds is through healthful, natural habits of living.* Wholesome food, outdoor exercise, proper clothing, and plenty of sleep are our best weapons against both colds and the more serious illnesses which sometimes follow colds (see page 313).

Most of us spend the winter in heated houses and in warm clothes. The natural heat-regulating mechanism of our bodies is thus given too much help for its own good, and as a result is apt to fail us when we most need it. That is why you may feel a chill when your clothing gets wet. Wet clothing and wet feet bring about a rapid loss of heat from the body and seem to lower the average person's resistance to colds. If you are exercising vigorously, wet clothing is not so likely to be followed by a cold, but it is better to take no chances. It is more pleasant to change clothing than to sniffle and cough for two weeks.

Another sensible precaution against colds is to avoid people who have them. Colds are "catching" (*contagious*). Although your natural resistance may protect you, it is much safer to avoid exposure. Coughing, sneezing, and spitting are dangerous to the health of near-by people. The handkerchief is helpful in reducing the danger, but too many people do not take the trouble to use it. Which of the people shown on the opposite page are you like?

What kind of sneezer are you?

Exercise. Keep a record of the number of absences from school on account of illness from colds. What can you do in your school to control the causes of colds?

Diseases That May Follow Colds. Colds in themselves are not dangerous, but while a person is suffering from a cold, dangerous diseases may develop. There are very good reasons for believing that *a cold makes one an easier prey to other diseases.* Among the serious disorders that may develop as after-effects of colds are sinus trouble, influenza, bronchitis, pneumonia, and tuberculosis. The person who says he will "wear off a cold" by continuing at his work while he is running "only a slight fever" is not using intelligence in the care of his health.

Exercise. Which disease has the highest death rate in your community? What one is the most common? If there is a public health department in your community, ask for this information. Find out what is being done to help in the fight against disease. Someone in the department would probably be glad to come to your school and talk to you about community health.

The "catching" diseases are generally more common in winter than in summer, because we live indoors more in the winter and associate more closely with other people. You cannot catch another person's illness unless you allow the germs of his disease to get into your body. This may happen if you get too close to the diseased person, and especially if you and the diseased person are careless. Diphtheria, scarlet fever, chicken pox, and whooping cough are among the contagious diseases which are most common in winter.

The cause of diphtheria is well known. It is brought about by *bacteria* (plants so small that they can be seen only through a microscope) which for some reason seem adapted to grow in the human throat. (Bacteria of this sort which cause disease are known as germs.) The little diphtheria germs are hurled from the throat when a person who has the disease sneezes or coughs. They cannot remain alive in the air very long. If, however, you are close to the sick person, some of the living bacteria may be carried to your throat in the air you breathe. Bacteria may be transferred on pencils or other objects, especially those which the sick person may have had in his mouth.

The tiny diphtheria bacteria, or germs, produce others of their kind very rapidly. A single bacterium divides and becomes two bacteria. Each of these may divide and form two more. A single germ may, therefore, be the parent of many germs in a very short time. Bacteria, like other living things, must use food and discharge the waste products formed from their food. The waste products from these bacteria are a deadly poison to man. It is for this reason that this disease is so dangerous.

The poison formed by bacteria which cause such diseases as diphtheria is called *toxin*. The proper treatment is to

destroy the effects of the poison. You probably know that the treatment for diphtheria is the use of antitoxin ("anti" means "against"). Antitoxin works against the effects of the diphtheria toxin. Before the discovery of antitoxin, diphtheria was one of the most-dreaded diseases. Today it is not so terrible because we know how to control it. If antitoxin is used promptly after the first symptoms appear, the illness is usually not serious.

Scarlet fever is another dreaded disease of winter. It is very contagious, but the cause of the disease has not yet been discovered. Fortunately during the past several years there has been a marked falling off in the number of cases. Smallpox, too, is a terrible disease that man has controlled through his intelligence. It is estimated that in the eighteenth century over sixty million people died in Europe

Vaccination has helped to make smallpox a rare disease

Ewing Galloway

alone as the result of smallpox! Even in the United States epidemics were fairly common. Smallpox is a highly contagious disease and unless guarded against spreads rapidly. Today, as the result of vaccination and other measures of prevention, it is very rare in Canada and the United States.

The Illnesses of Summer. So far we have studied diseases which are most common in winter. What are the diseases of summer? At one time the most-feared disease of the warm months was typhoid fever. It is one of the great triumphs of the science of public health that this disease need be feared no longer.

Typhoid fever is caused by bacteria that enter the body with our food and then take up residence in the intestines. It is a filth disease. Since the germs live in the intestines, it is clear that we cannot "catch" typhoid fever unless some of the waste products from a person suffering with the disease get into our foods.

It was learned from study of the causes of this disease that the germs are most likely to enter our bodies through water and milk. As public measures were developed for the better protection of water and milk supplies, typhoid fever began to become less common. For several years in a Midwestern city the death rate from typhoid was over 120 per 100,000 inhabitants. In 1907 a new filtering plant was added to the water system, and by 1910 the rate had dropped to slightly over 20. Today the disease is practically unknown in that city. The same is true of most other cities in this country.

It was learned, too, that typhoid germs may be carried from filth to food by flies. After this discovery most cities put on campaigns to destroy houseflies, as well as to clean up filthy places. These campaigns have been fairly suc-

cessful, and in sanitary communities houseflies are not at all common. The result is that there have been no serious outbreaks of typhoid fever in large American cities for years. Our greatest danger from this disease today comes during vacation trips, when we are away from carefully controlled water and milk supplies.

Exercise. Prepare a culture plate of agar or beef broth and gelatin. Allow a fly to walk over the surface of the plate. Then cover the plate and keep it at room temperature for four or five days. Examine for signs of bacterial growth. How clean are a fly's feet?

Malaria is another summer disease in the temperate zones. But this, like most other severe summer diseases that once caused suffering and death in the temperate zones, is now pretty well controlled. One very important feature in man's control of his environment is his control of the conditions that might allow contagious diseases to develop. But he must continue the fight. If he rests on his victories, these diseases will certainly break out again.

This greatly enlarged footprint of a fly was made through the growth of bacteria which the fly left behind when it walked over a culture of agar[1]

Exercise. Has there been a severe epidemic of any contagious disease in your community during recent years? If so, in what season of the year did it occur? How many cases of illness were

[1]From the film *Secrets of Life*, British Educational Films, Ltd.

there? What was done by the board of health to bring the epidemic under control?

How to Live a Healthy Life. Through the use of your intelligence you may do much to protect yourself against illness. There is no one rule which can be applied to everybody. It may safely be said, however, that all of us might better let drugs alone unless they are prescribed by a physician. Many people are unintelligent in the use of drugs, and it is certain that most of the medicines that are swallowed do no good. When a person really needs medicine he should avoid the possibility of taking worthless or dangerous kinds by seeking the advice of a physician.

Above all, try to live a simple, natural life with plenty of wholesome food, outdoor play, and sleep. If you do this regularly and faithfully, you will not need a physician's advice.

THE BEST CONDITIONS FOR MAN

Good and Bad Adaptations. Though men live many different kinds of lives in many different places on the surface of the earth, it does not follow that all ways and places of living are equally well suited to the needs of human beings. *Though man is easily the most adaptable living thing in the world, there are many conditions to which he adapts himself very poorly or not at all.*

There is no good adaptation, for example, to continual noise, continual worry, or continual overindulgence in alcohol or tobacco. These and certain other harmful conditions and habits are the products of civilization. No person has ever discovered good methods of adaptation to them. The only intelligent way of meeting such conditions and habits is to realize their danger and avoid them.

Standard Silica Corporation

[T]he mask which this man is wearing is an artificial adaptation to a dangerous con-[d]ition. It helps to keep the powdered silica with which he is working from entering his lungs and producing a fatal disease

Exercise. Make a list of common habits of civilized men which you consider poor adaptations. Include any habit which you consider harmful if continued over a period of years.

In the same way there are certain occupations of men which are harmful. It would seem, for example, that the human body cannot naturally adapt itself to places where much dust exists, as in coal mines. The fine grains of mineral matter in time destroy the tissues of the human lung. An attempt to overcome the danger of working in dusty places is illustrated on the preceding page. A good adaptation to a life of inactivity in an office is also difficult unless outdoor air and exercise are taken regularly.

Exercise. Make two lists of occupations, labeling one "Good Adaptations Possible" and the other "Good Adaptations Improbable or Impossible." Enter as many occupations as come to your mind, using your own judgment as to where they should be listed. Then compare and discuss your lists with those of your classmates.

Huntington's Search. Some years ago Ellsworth Huntington, a noted American geographer, attempted to find out how human health and energy change from time to time, and what causes the changes. He studied factory workers who did the same thing day after day, to see how their output of work varied. He collected records of the health and work of school children through the year. He studied the health and death records of whole communities of men and women.

He came to the conclusion that *climate and weather influence the health and energy of human beings more than do any other conditions.* Since his studies represent the

Ewing Galloway

hese people of French Indo-China have had their energy sapped by the intense heat

most careful attempt yet made to discover the conditions to which man can best be adapted, we shall devote the rest of this section to an examination of his chief conclusions.

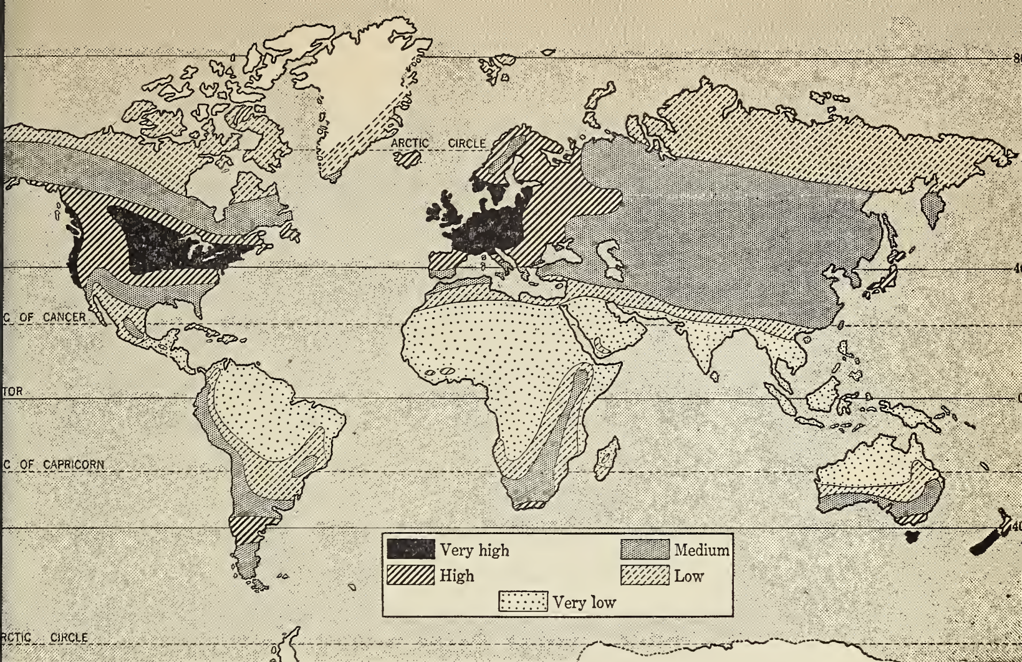
The Best Temperature for Man. One need only visit a tropical city to see that its people are neither so healthy nor so energetic as the people of cities in the temperate zones. We all have felt lazy and weak during a spell of hot weather, and can imagine how we should feel if such a spell lasted for months instead of days. In the same way we can understand why people who live in frigid climates are not so healthy and energetic as those who live where intense cold waves last only a few days at a time. In short, we can understand that *some climates are too hot and others too cold to provide the best environment for man.*

After very careful observations Huntington came to the conclusion that human beings are healthiest and most energetic where temperature averages close to 64° F. This means that the mercury drops to about 56° or 60° F. at night and rises to about 68° or 72° F. during the day. He found, however, that the best temperature for mental work is considerably lower than this. When the outdoor temperature averages about 40° F., our minds seem to be most active.

Both physical and mental energy must be present in any good human adaptation to environment. Huntington believes that the best climates for man are those where the average summer temperature is near 64° F. and the average winter temperature is near 40° F. *Such climates may be found at several places only in the temperate zones.*

Exercise. Look up in a textbook of meteorology (science of weather) maps which show average July and January isotherms. (Isotherms are lines which are drawn through places having the same temperature at the same time.) With a piece of tracing paper transfer the 70° July isotherms to an outline map of the world. Then do the same for the 40° January isotherms. The lines on your map will set off belts in both the Northern and the Southern Hemispheres which in general contain the best temperature conditions for man.

The Best Humidity for Man. Huntington's work has shown very clearly that a fairly moist climate is best for man. The equatorial rain forests are too wet, the deserts too dry, to be favorable to the greatest possible health and energy. It would seem, for example, that when the average temperature is close to 64° F., the relative humidity is most favorable when it is close to 80 per cent for the



'his map shows how human energy is distributed. Notice that the most energetic people (indicated by solid black) live in the north temperate zone

average of day and night. (Review Chapter Five to refresh your mind on relative humidity.)

With an average relative humidity of 80 per cent and an average temperature of 64° F., the air in the daytime warms up to around 70° F. and the relative humidity falls to around 65 per cent. At night the temperature drops to around 56° F. and the relative humidity rises to 100 per cent. Since air cannot hold moisture beyond 100 per cent, dew forms on the ground during the night.

If the relative humidity falls below 40 or 50 per cent at any time, the nose, throat, and skin begin to get too dry. If, on the other hand, relative humidity goes above 70 or 80 per cent, with a corresponding rise in temperature above 72° or 75° F., moisture does not easily evaporate from our bodies. In this condition our heat-regulating mechanism fails to keep us comfortable. Do you see why we are apt to be nervous and tired during a period of very

dry weather and also during a period of very hot, damp weather?

The Importance of Changes in Weather. A climate may be very good with reference to temperature and humidity and still lack the frequent changes in weather which man seems to need. Huntington's studies show that human health and energy are highest where the seasons are most marked and where cyclonic storms bring frequent changes in weather. On page 325 is a map which Huntington made to show the distribution of human energy throughout the world. Notice that the most energetic people live in the belt of westerly winds, where temperature, humidity, and weather changes are most favorable to the needs of human beings.

The Ideal Climate. It is easy to see that no place in the world can have absolutely ideal conditions of temperature, humidity, and weather changes *all the time.* But wherever we live we can improve the climate because we can improve the conditions in our houses. With a little care we can keep the winter temperature of our houses very close to the ideal. With modern systems of ventilation it is also possible to keep the relative humidity of buildings close to the ideal.

Exercise. Take observations of temperature and humidity in your house and in your schoolroom. How nearly do these buildings approach an ideal climate? How could you change their climate so as to improve your health and increase your energy?

Other Adaptations of Man. Temperature, humidity, and weather changes are, of course, not the only conditions to which we must be adapted. We must also be adapted to

our work, to our play, and to our social life. These are extremely complicated problems in the modern world and problems for which there are no general or easy answers. There is no single best kind of adaptation to life for all people. Part of the fun of living, indeed, is that adaptation is a problem. Forever striving to improve the conditions under which we live makes life an interesting adventure.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Unlike most other living things, man is adapted for a very narrow life in a very limited area.

2. The artificial adaptations of man are much more effective than the natural adaptations of other creatures.

3. Due to the fact that men live in clothes and houses, their natural heat-regulating system no longer works.

4. Dark clothing is best in winter because it is a good conductor of heat.

5. Medical science has progressed so far that men now have artificial means of keeping healthy without the help of outdoor exercise, air, and sunlight.

6. The cause and cure of the common cold are well understood.

7. Being sneezed upon by a person with a cold cannot hurt you if you are in good health.

8. "Toxin" is another name for the germs that cause disease.

9. Because of his great intelligence, man can adapt himself to practically any habits or conditions he desires.

10. The range of temperature which is best for man is between 70° and 80° F.

11. Dry climates are more healthful than moist climates.

12. Frequent storms tend to make human beings tired and nervous.

Questions for Discussion

1. How many examples can you give which will support the statement "Most living things are adapted to live within a narrow range of conditions"?

2. How many examples can you give to support the statement "Man can adapt himself to living within a wide range of conditions"?

3. The statement is made, "Man is best adapted to live in the temperate zones, for it is there that we find the greatest nations of the world." Do you think this is so?

Things to Do

1. Secure several samples of clothing materials representing a number of colors and a variety of fabrics (wool, cotton, silk, and rayon). Test the heat-absorbing power of each by covering the bulb of a thermometer with the sample and exposing it to sunlight. Observe and record the rise in temperature in each case. Do your experiments in pairs; that is, take a piece of woolen cloth and a piece of cotton cloth of the same color and test at the same time. Then try two samples of the same fabric, one light and one dark. Test several pairs in this manner and keep careful records of your results. What conclusions can you draw from these experiments?

2. Prepare a chart of common contagious diseases. Arrange the chart in three columns. Place the names of the

diseases in the first column. In the second column, opposite each disease listed, state how the disease germs get into the human body. In the third column give the methods used to control each disease.

3. See what figures you can find to show how medical science has succeeded in lowering death and illness rates. Check back over a period of fifty years for the United States and Canada or, if you wish, for your own community. Prepare graphs showing the figures you find, and present them to your class.

4. What do you know about fake medicines? Are all the medicines advertised in the newspapers safe to take? From time to time the American Medical Association has issued books on fakes in medicine. Your library probably has these. See what you can find in them that you think might be of interest to your class.

5. Look up the ways of life practiced by (*a*) the Eskimos of Alaska, Greenland, or Siberia; (*b*) the Maoris of New Zealand; (*c*) the Bedouins of Arabia; and (*d*) the Bantus of Africa. How does different climate help to explain the different adaptations of these peoples?

UNIT FOUR

THE CHANGING LANDSCAPE

Sky, air, plants, and animals—all are forever changing.

Where can we go to find something that does not change?

"We can go," you might say, "to the rocky surface of the earth on which we live, to the fields and hills and mountains.

"These surely do not change."

If you said that, you would be wrong.

Though changes in the landscape are very slow, they are always going on.

Rocks are forever crumbling; frost, wind, rivers, and glaciers are forever changing the expression on the face of the earth.

Earthquakes and volcanoes are forever shifting rocks and changing the very features on the face of the earth.

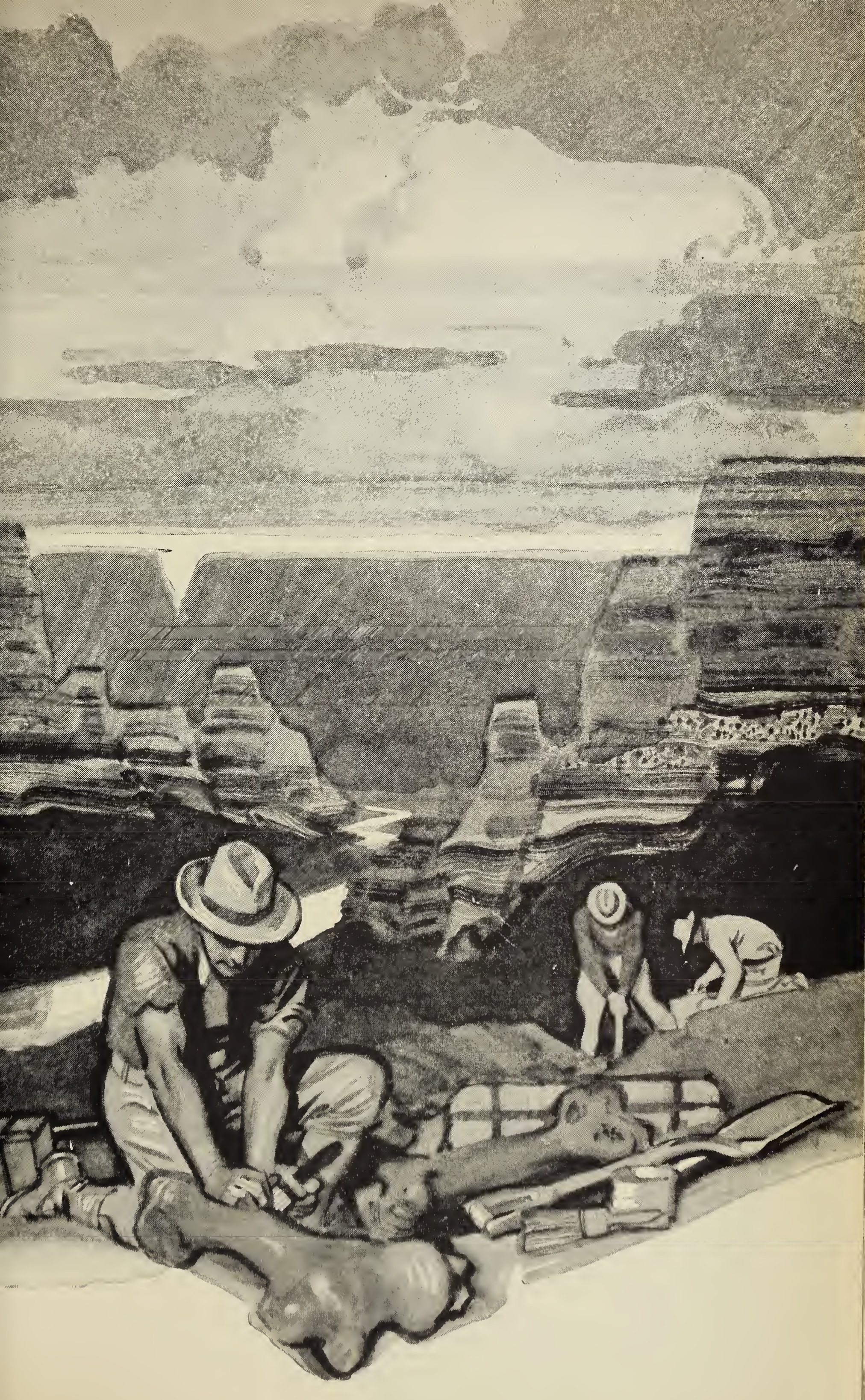
Not only this but plants and animals have greatly changed with the changes in the landscape.

If you were to be carried back into the far-distant past of the earth, you would probably think that you had been carried to another world.

You would see some very strange lands and some very strange creatures living there.

You would be excited and thrilled by some of the mightiest changes that have ever taken place.

Unit Four of this book will try to show you what these changes have been and how they have come about.



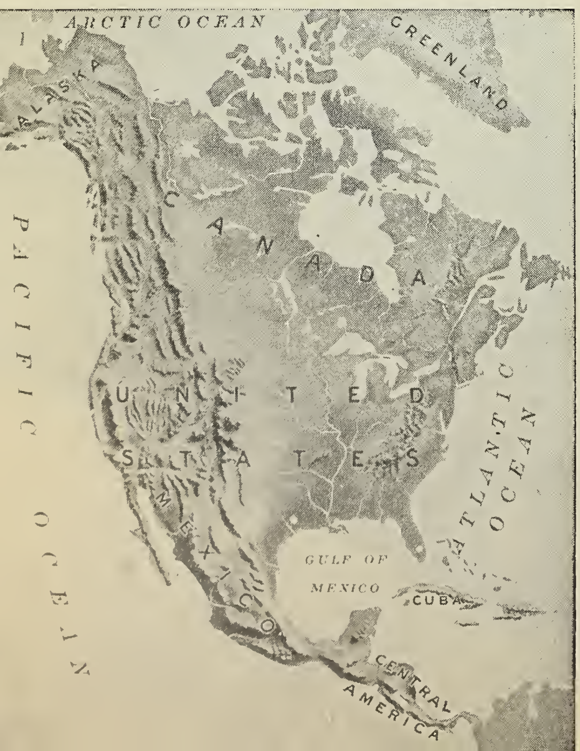
CHAPTER THIRTEEN

What Forces Are Tearing Down the Lands?

HOW ROCKS ARE BROKEN AND CARRIED AWAY

The Face of North America. Imagine that you are looking down on the surface of North America from the surface of the moon. With the help of a good telescope you could see the whole continent laid out before your eyes, as in the map below. Along the west coast high ranges of mountains troop all the way from Alaska to Mexico. Eastward these ranges give way to the plateaus and plains which make up the central part of the continent.

If you could look at the earth through a telescope on the moon, this is how North America might appear



You notice the mighty Mississippi, with its tributaries reaching far to the west and east and its mouth in the Gulf of Mexico. You notice the mighty chain of the Great Lakes stretching along the boundary between Canada and the United States, and bordered both north and south by rich agricultural lands. You see the Appalachian Mountains lying parallel to the eastern coast, neither so high

nor so long as the Rockies and the other ranges to the west. Finally you see the broad rich lowlands along the Gulf and southern Atlantic coasts.

As you look at this sight you may wonder how it came to be. How were these mountains, plateaus, plains, rivers, lakes, and lowlands formed? Were they there from the beginning of time? Will they remain there until the end of time? Or have they been changing since they first came into existence?

The Changing Landscape. As you look down upon North America from the moon, the landscape does not appear to change. It looks as quiet and solid as a statue. But the scientists who study the earth know that the lands are not so quiet and solid as they seem. Mountains as high as the Rockies have been many times built up and torn down since the earth began. Rivers and lakes have come and gone, coast lines have been widely and frequently shifted. Such changes as these have not been unusual in the history of the earth. Indeed *they have been going on all the time.* They are going on now. They take place so slowly, however, that we do not ordinarily notice them.

How then, you may ask, do we know that they are taking place at all? To answer this question we must go to the geologist. It is he who knows most about the earth and her ways. It is he who can sharpen our eyes to see many great changes which we might otherwise blindly pass by.

What Freezing Water Does to the Rocks. The geologist will tell us that *many little things often repeated bring about mighty changes in the appearance of the earth.* One of these little things is the water that trickles into the cracks of the rocks and by freezing there causes the rocks to break.

Exercise. How to show that water exerts a pressure when it freezes: Fill a small bottle with water and close it with a cork or a rubber stopper. Place the bottle in a beaker, as shown in the photograph below, and cover it with a mixture of cracked ice and salt. (Dry ice can be used instead of the cracked ice and salt, but be very careful never to touch dry ice with your naked fingers.) Keep the bottle covered until the water freezes. What happens? Does freezing water exert any pressure?

What happened to the bottle in the above experiment also happens to rocks when water freezes in their cracks. The pressure developed by water as it expands with freezing is about two thousand pounds per square inch. This is enough to break very strong rocks and to pry apart very heavy ones.

The action of freezing water produces great aprons of loose rock on the sides of mountains and cliffs. Such loose rock is known as *talus*, and a good example of it is shown on the opposite page. The pieces of loose rock at the foot of this great cliff were broken from the rocks higher up mainly by the pressure of water freezing in cracks.

This boy is proving that water exerts pressure when it freezes

What Changing Temperature Does to the Rocks. The part that temperature plays in the breaking up of rock is not confined to the effects of freezing water alone. *Temperature changes can break rocks—whether there is water in the cracks or not.* Did you ever crack a glass

by pouring hot water into it? If you did, what made the glass break? Let us see.

In the first place, the glass was cool. When you poured hot water into it, you made the inside of the glass expand very rapidly with the heat. The outside of the glass, however, did not expand so rapidly because glass is a poor conductor of heat. This unequal expansion between the inside and the outside set up a powerful strain. Glass is brittle and cannot stand such strain, so it cracked.

A vessel made of copper, silver, or aluminum would not have broken under the same conditions. These materials are better conductors of heat and, unlike glass, are not brittle. Rocks, on the other hand, are like glass. They break when their surfaces are rapidly heated. Like glass, rocks also break when their surfaces are rapidly cooled.

Exercises. How to prove that rapid cooling causes glass and rock to break: Heat a piece of glass tubing until it glows. While it is hot drop it into a basin of cold water. What happens?

Very slowly heat a small piece of rock in a flame until it is very hot. Then lift it with a pair of tongs and drop it into a pail of cold water. Try samples of two or three different kinds of common rocks,—for example, one of granite, one of limestone, and one of shale. What happens in each case?

The loose stones at the foot of this cliff were produced very largely by the pressure of water freezing in the cracks of the rocks above

Northern Pacific Railway

National Park Service

Temperature and chemical changes on a rocky surface may make it peel off in great curved slabs

Think now of the rocks on the side of a mountain in a region where it is hot in the daytime and cold at night. The rays of the sun heat the rocks during the hours of daylight and cause the outside to expand more rapidly than the inside. At night, after the sun sets, the heat is lost by radiation. The outside of the rocks, which expanded more with the heat than did the inside, now contracts more with the cold than does the inside. Strains are set up which, when repeated daily over a period of years, will cause the mountain slowly to chip away.

Water freezing in the crevices and acids gnawing at the mineral grains also help tear rocks to pieces. In some cases rocks chip off as though they were built of curved shells like an onion. Look at the photograph above. This shows the result of temperature and chemical changes upon a rocky surface.

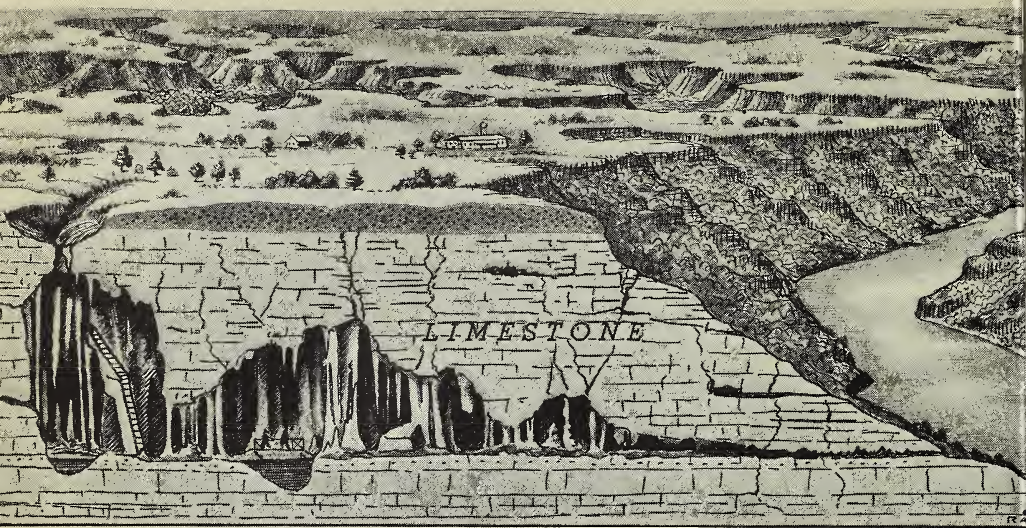
How Water Dissolves Rock Material. Many of the materials of which rock and soil are made can be dissolved in water. As rain seeps into the cracks of the rock and the pores of the soil, these soluble substances are dissolved.

Exercises. How to show that mineral matter dissolves in water: Place a teaspoonful of clean table salt in a glass of water and stir it until the salt dissolves. You now have a solution which looks just like pure water. Heat the solution until all the water has evaporated. What do you find?

Evaporate a glass of clean spring water or some ordinary drinking water. Do you find any mineral material in the bottom of the glass?

The water of springs, brooks, and rivers contains dissolved mineral matter which was picked up from the rocks and soil over which the water moved. This soluble matter is carried in time to the oceans. The water from a spring or stream does not generally taste salty, because it contains only a little salt. The salt, however, slowly gathers in the oceans, where thousands of streams drop their cargoes. That is why ocean water is so salty that it cannot be used for drinking. When water evaporates from the ocean, the salt is left behind. Do you see, then, that each year the oceans are a little more salty than they were the year before?

Of all the mineral matter which is dissolved in sea water, common salt (sodium chloride) is the most abundant. Many other substances, however, are present. Compounds of more than thirty elements have been found. All these substances came from the continents and prove that water helps to break down and carry away rocks by dissolving them.



Mammoth Cave in Kentucky is the result of an attack by acid waters on limestone rock

What Acid Does to the Rocks. If you have ever visited or seen pictures of a limestone cave, you have probably asked the question "How was this formed?" Limestone is one of the most common rocks in the crust of the earth. Many regions have underlying layers of such rock, many feet in thickness. Limestone dissolves slowly in pure water. If the water contains a small amount of acid, however, the rock dissolves more rapidly.

Exercise. How to show the effect of acid on limestone: Place some crushed limestone in pure water. Is there any sign of change? Then add a small amount of dilute hydrochloric acid to the water. Stir until well mixed. Is there now any sign of change? Place a very small piece of limestone in a test tube and cover it with strong hydrochloric acid. Watch the chemical action for a time. What happens to the limestone? If water carrying a small amount of hydrochloric acid were to trickle down through the cracks in limestone rock for many years, what do you think would happen?

The most common acid in nature is *carbonic acid.* This is formed when carbon dioxide is dissolved in water. Carbonic acid is a very weak acid, but it will slowly dissolve limestone. As a result of the chemical action of acid water which seeps into the pores and cracks of limestone, the rock is slowly carried away in solution.

Let us look now at the effects of this action in a typical cave, such as Mammoth Cave in Kentucky. Here a great hole has been formed in layers of limestone about three hundred feet thick. In places the cave is as much as three hundred feet wide, and the distance from floor to roof may be a hundred and twenty-five feet. The space within the cave was once solid rock. The diagram on the opposite page shows how an enormous cavern may be cut into rock by the action of water carrying a small amount of carbonic acid in solution.

Below you may see parts of the interior of a limestone cave. Pillars called *stalagmites* seem to grow like giant mushrooms from the floor. Masses called *stalactites* hang from the ceiling like icicles.

Limestone caverns contain many weird and beautiful sights

Water carrying limestone and carbon dioxide in solution forms these strange and beautiful growths when it leaks through the roofs of caverns. The carbon dioxide gas slowly escapes from the dripping water by evaporation, leaving on the ceiling a deposit of lime. As the deposit gets larger, the stalactite grows downward from the ceiling. Water falling on the floor causes stalagmites to be built upwards as a result of the same kind of chemical action.

The changes that go on while caves are forming are extremely slow. You would realize the length of time it took to form a cave if you tried to get limestone by evaporating water collected from the roof of a cave. Huge quantities of water yield only small amounts of solid substance. But *small changes continuing for an enormously long time have made Mammoth Cave and many others like it.*

What the Wind Does to the Rocks. Have you ever been caught in a severe windstorm? Whether you have or not, you have no doubt seen pictures of trees and buildings destroyed by the wind. Perhaps you have seen a strong gale raising clouds of dust from a dry road or field. If you have been to the desert or the seashore, you may have seen sand dunes similar to those pictured on the opposite page. Dunes of this sort are the work of the wind.

The force of rapidly moving air may be illustrated by an observation which is familiar to city dwellers. A stone or brick building becomes dirty from the soot and dust in the city air, and is cleaned by a process which is known as *sand-blasting*. Air is compressed by an air pump and allowed to escape through the nozzle of a hose. Sand is carried in the rapidly moving air and is blown against the face of the building. The force of the sand blast quickly cuts off the dirty surface of the stone.

Three Lions

Sand dunes of the Sahara Desert make fine playgrounds

When sand is blown by the wind against a rocky surface, it cuts the rock in the same way. The photograph below illustrates the effect of wind-blown sand upon rocky surfaces. More sand is carried along near the surface of the earth than is carried higher up. For this reason rocks are worn away fastest near the ground and tend to take the shape of huge mushrooms.

A strong wind over the desert may carry an enormous amount of sand. It has been estimated that a single storm in the Sahara Desert carries five hundred thousand tons of sand into the air! Some of this is blown across the Mediterranean Sea into Europe. Parts of Kansas and Nebraska are covered to a depth of as much as twenty feet with fine earth which was carried and then dropped by winds from the west. In China there are similar deposits, in some places several hundred feet thick, which have been carried by the westerly wind from the high, dry plains of central Asia.

Sand blown along the surface of the ground helped to form this mushroom-shaped rock

David Lavender

Exercise. Obtain a rock specimen that has been exposed to the weather. Break it with a hammer and compare the fresh surface with the surface that has been exposed to the weather. Are there any signs that this specimen has been or is being attacked by any of the forces you have studied?

WHAT RUNNING WATER DOES TO THE EARTH

Erosion. When rocks are broken and carried away, they are said to be *eroded.* The process is called *erosion.* The word "erosion" comes from a Latin word which means "to gnaw away." Just as a mouse gnaws at a piece of cheese, so frost, heat, acids, and wind gnaw at the surface of the earth. Given enough time, such instruments of erosion can level the highest mountains in the world.

One of the most powerful of all the instruments of erosion is running water. How many brooks or rivers have you seen? Even if you have traveled widely, you have probably not seen a large percentage of all the streams that flow over the surface of the earth. When you think of the millions of streams which day and night for years on end carry rocky material from the highlands to the lowlands, you can get some idea of the importance of running water as an instrument of erosion.

Exercises. How to study the force of running water: At one end of a large flat pan place a pile of soil. Shape the pile with slopes like a small hill. Slowly pour water on the slopes, varying the conditions in as many ways as you can. Use different kinds of soil, including coarse sand and pebbles, and note variations in the amount of "wash," or erosion. Next change the steepness of the slopes and notice how this influences the amount of soil carried by the water. Then try pouring the water more rapidly and see how that affects erosion.

Notice the water that flows down the slopes near your home or your school after a heavy rain. Dip up some of this water in a glass tumbler and observe it closely. Is it clear or muddy? Where did the mud come from? Where is it going?

These children are studying the erosion of soil by running water

What Muddy Water Is. The amount of water that falls on the earth as rain is really very great. *One inch of rain on one square mile of land is equal to about seventeen million gallons.* If you could dip up this tremendous quantity of water glass by glass, each glassful would be muddy. The mud in every case would be composed of tiny particles of soil. By examination with a microscope you could see that the soil is composed in part of tiny pieces of rock.

Exercise. Place a small amount of soil in a test tube and shake it well with water. Place a drop of this muddy water on a microscope slide and examine it with the low power of the microscope. Do you see particles that resemble small rocks?

Follow some water as it flows down a slope. You will see that it runs in little gullies, and that the steeper the slope, the faster the water flows. The faster it flows, the more

soil it can carry. Examine the foot of a hill and you may see where particles of soil have been deposited by running water. Such familiar observations prove that enormous quantities of soil are carried from higher to lower places by the water that falls when it rains.

Erosion and Conservation. What is the effect of all this erosion? A scene like the one shown below is all too common in many sections of the United States. The gullies in the hillsides have been cut out by running water, and the soil that was removed has been carried to lower levels. In many places the rich topsoil is being stripped off the land by erosion and carried to the sea. Many thousands of square miles of once valuable farm lands are being destroyed.

What can we do to stop such frightful waste? The answer to this question is too long to give here, and too

Erosion by running water has removed the valuable topsoil from this hill

U. S. Forest Service

important to be squeezed into a chapter which deals with other things. But remember that there is an answer to the question of how we can save our farm lands from erosion. This question and other questions which deal with the conservation of our natural wealth will be taken up at length in a later chapter.

Exercise. You have read from time to time about the floods which cause hundreds of thousands of dollars' worth of damage all over the world. Many of these floods are made more severe because of land erosion. See if you can find out why this is so and what our government is doing to prevent such floods. Are similar steps being taken in other lands?

How Large Stones Are Carried by Streams. Running water can carry rock material which is much larger than mud. Large rocks, known as boulders, are often carried long distances. Look at the picture below. As the water swirls

Boulders rolled down the bed of a stream have their edges chipped and rounded

round a stone which is resting on sand or soft dirt, it carries this loose material away from the lower side of the stone. After a time the stone will turn over into the hole that was cut out by the water. As the process is repeated, the boulder moves slowly downstream.

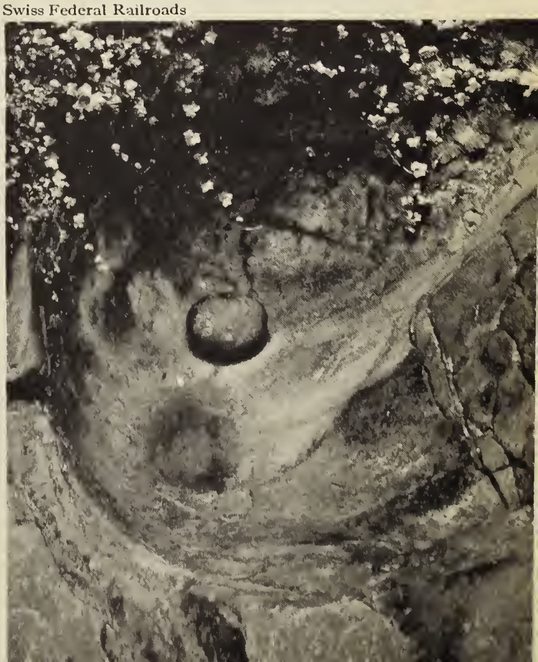
The stone may strike against other stones as it rolls, and small pieces may be chipped from it. This process tends to wear off the sharp edges of rocks which are traveling in streams. Stones that have been carried for some distance by running water are often nearly round. Notice the rounded edges of the rocks in the photograph on page 348.

How Rivers Erode Their Channels. With time the bed of a stream is cut deeper and deeper by the grinding action of the rocky material which is carried by the water. In some places small pebbles may be caught in the surface over which a stream is moving. The force of the flowing water drives the pebbles round and round in little whirlpools. The rubbing (friction) of the moving pebbles against the underlying rock grinds the hollows deeper and deeper, forming *potholes* similar to those shown at the right.

As you travel along a river you may see hills along both sides. These have been formed by the action of the running water as it cut its way from higher to lower elevations. In certain places you may see rocky cliffs along

This pothole was once part of a stream bed. It was ground out by stones that were turning round and round in a whirlpool

Swiss Federal Railroads



Chicago Aerial Survey Co.

Streams may cut deeply into the rocks over which they flow

rivers. These, as illustrated above, are striking proof that the forces of flowing water may wear away solid rock.

The Work of the Mississippi. The Mississippi River drains hundreds of thousands of square miles of land. Rain which falls over all this vast territory flows toward the mighty river. Each drop of water gathers mud as it travels along. During the course of time *many cubic miles of earth and rock have been carried away by this one river and its tributaries!*

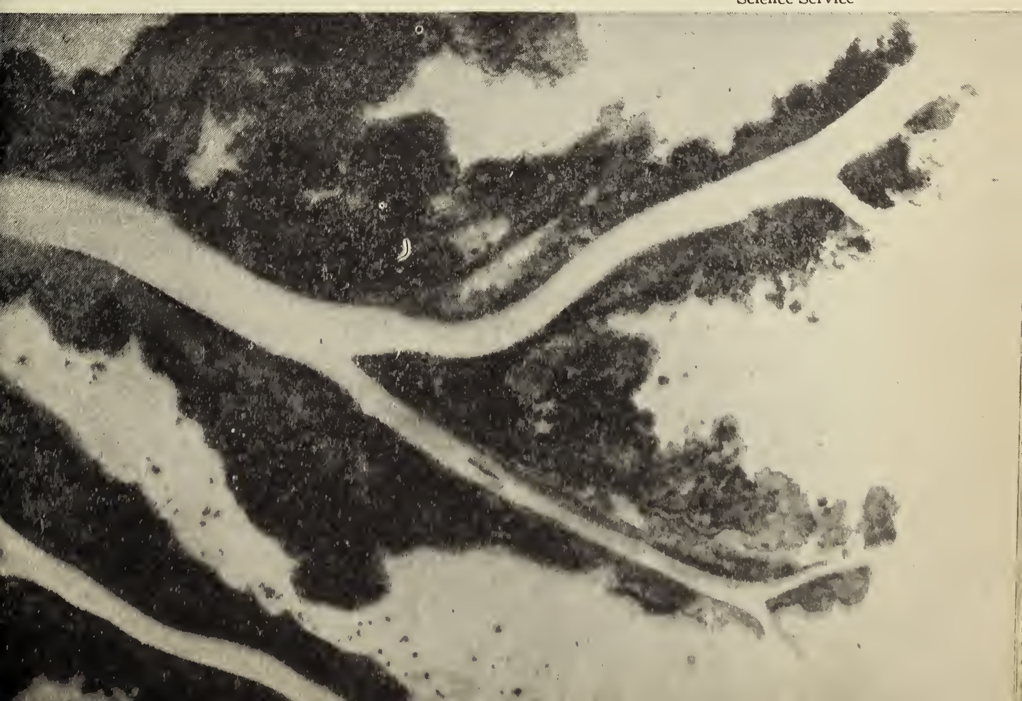
All stream beds are slowly cut down to lower and lower levels. The material that is cut away is carried, in the case of the Mississippi, toward the Gulf of Mexico. In time of flood the current is swifter than usual, and large quantities of mud are moved. When the flood is over, some of these particles are dropped along the banks—only to be picked up again and carried along by the next flood.

Below is an airplane view of part of the delta at the mouth of the Mississippi River. (River deltas take their name from the Greek letter Δ, or delta, because they are more or less triangular in shape.) The Mississippi delta, like all other deltas, was formed from the particles of broken rock which were brought down from the highlands by the river. It has been estimated that in one year enough material is laid down on the delta to form a layer of soil one foot thick over an area of two hundred and sixty-four square miles.

Exercise. The Mississippi River system is one of the largest river systems in the world. Do you know how long it is? where it begins? which important rivers are parts of it? Look up this information and draw in this system on an outline map. Compare your map with maps in geography books which show the regions that produce corn, wheat, cattle, hogs, and cotton. What relationships do you find?

The Mississippi delta is made of loose rock which the great river brought down from the highlands to the north

Science Service



The Danube. The mighty work of river erosion can be seen in all parts of the world. The Danube River drains a large part of Europe. (This river is not "beautiful blue," as the famous waltz would have it, but dirty yellow as a result of the mud it carries.) Its delta in the Black Sea is about a thousand square miles in area. Like other large rivers, the Danube is filling the sea with sediment brought from far away. In this case the sediment comes from the Alps and the Carpathian Mountains and from the valleys and plains along the way.

The Amazon. The Amazon River of South America carries the largest volume of water of all the rivers in the world. Though much of the sediment carried from the Andes Mountains is deposited before it reaches the ocean, great quantities of gravel, sand, and mud are carried to the Atlantic. Indeed, so fast is the river flowing at its mouth that it carries its load of broken rock far into the sea, and does not form a delta. Amazon mud may be seen in the Atlantic a thousand miles from shore, where its dark appearance contrasts with the clear blue of the ocean water.

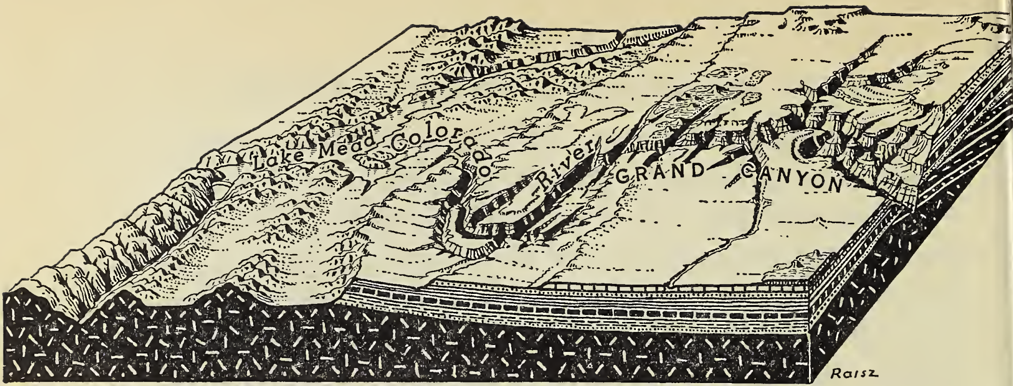
The Nile. The Nile River drains a large portion of equatorial Africa. It flows northward through the Sahara Desert to the Mediterranean Sea. The water of the upper Nile flows very rapidly and carries a large amount of broken rock from the highlands at the head of the river. Farther down, the river flows over more nearly level ground and slackens its speed. Rock particles from the mountains of central Africa, and the rich soil from the rain forests and the jungles, are carried to lower levels, where they are deposited as sediment.

During the rainy season the Nile overflows its banks. When it creeps back into its channel, a layer of rich sediment is left behind. This flooded land, though it lies in the heart of a desert, makes one of the richest farming districts in the world. The lower Nile of the ancient Egyptians was the seat of one of the oldest civilizations on earth. The people who lived in this region realized the value of running water, for they worshiped the river that made their civilization possible.

Exercise. Three of the old Egyptian gods were Osiris, Isis, and Apis. There is a legend about each of them and the story of the Nile floods. See what you can find out about them in an encyclopedia.

The Colorado. In northern Arizona, where the Colorado River cuts deep into the rocks of a high plateau, lies one of the greatest sights in the world. Though there are many canyons along this river, the Grand Canyon is the deepest and the most beautiful. Here the river flows as a raging stream in a mighty gash in the plateau. It is possible to read from the walls of this canyon a long story of changes which have taken place on earth.

Perhaps sixty million years ago, according to the story of the rocks, there was no Colorado River. Most of the region through which this river now flows was then covered by the sea. (We know this because we can dig sea shells out of the rocks.) As time passed, powerful forces within the earth wrinkled and pushed up the entire region, forming the Rocky Mountains and the high plateaus of the Southwest. These changes went on so slowly that if there had been people living there at the time they would not have noticed them any more than people today notice similar changes which are taking place now.



The Colorado River is the greatest example of river erosion on earth

Through these millions of years of gradual change, the surface of the earth was elevated until places which had once been beneath the sea stood two miles or more above it. Rains fell upon these new highlands and the water flowed away, just as it does on our hillsides today. Such was the beginning of the Colorado River.

As the region was elevated more and more, the slope over which the river flowed became steeper and steeper. As a result, the water moved more and more rapidly and with greater and greater force. So the river cut downward during millions of years until *it now flows at more than a mile beneath the level of the surrounding country.* Above is a cross section of the Colorado River, *the greatest example of river erosion on earth.* Note the different layers of rock through which the river has cut.

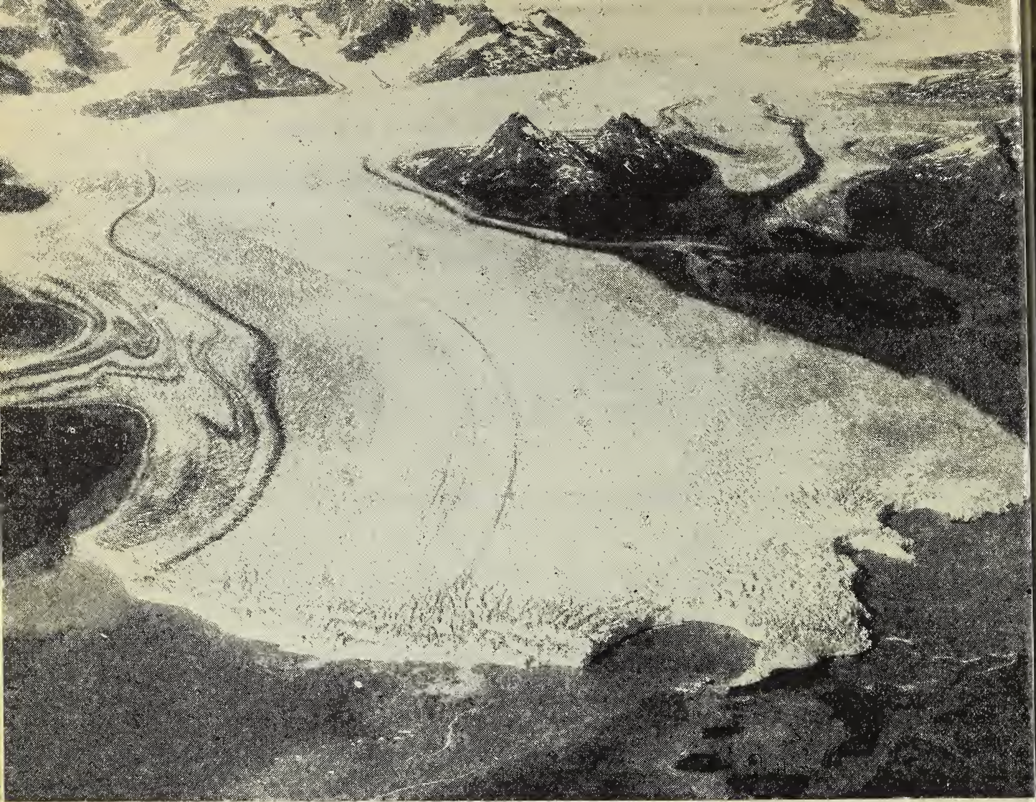
Exercise. Build a model or make a drawing to show the character of one wall of the Grand Canyon, following the drawing above. Indicate the different layers of rock by using different-colored paints.

The bed of the upper Colorado is still high above the level of the sea. The river still rushes rapidly down the slope to the sea, carrying large amounts of broken rock,

which fall into the water from the steep banks. It carries away about a cubic mile of this sediment every thirty years. This is deposited in the Gulf of California and in the lowlands through which the river flows before it finally reaches the gulf. While the change is hardly noticeable from one year to another, it is clear that if this process goes on long enough, the southern Rocky Mountains will in the end be completely worn away.

By studying the walls of the Grand Canyon, as shown below, a geologist can tell how these layers were formed. He sees limestone deposits that must have been laid down as mud while the sea covered northern Arizona, because remains of ocean plants and animals have been found there.

'he layers of rock exposed in the Grand Canyon were laid down as mud and sand by the waters of many past ages



Bradford Washburn

Glaciers are rivers of ice that flow, as a rule, a few inches to a foot a day

There are other rocks that must have been formed from soil which was deposited from streams that drained the land before the present highlands were formed. It is clear from a study of this canyon that the forces which wear away the surface of the earth today have been at work for a very long time.

All this is but part of the story of the changes that running water brings about. The observations which one may make while traveling along the banks of any of the great rivers of the world prove that water has been flowing on the surface of the earth for an extremely long time. They prove that during all this time water has been wearing down hills and mountains and carrying the broken material to the sea.

WHAT GLACIERS DO TO THE EARTH

Rivers of Ice. Glaciers are rivers of ice which take form only where more snow falls in winter than melts away in summer. The snow is thus able to pile up higher and higher until the weight of the snow above changes that below into ice. Such huge snowbanks are generally born in mountainous regions. When they have grown large enough, they lose their balance on the mountain sides, and begin to creep slowly down toward lower levels under the pull of the force of gravity.

The photograph on page 356 shows a typical glacier, or river of ice. It is flowing at the rate of a few inches or a foot a day. Though it moves so slowly that you cannot measure its movement with your eye, it carries a great deal of rock material which was broken from the mountain valley through which it passes. When glaciers such as this one reach lower and warmer elevations, their ends melt or

[T]his heap of gravel and boulders was dropped at the end of a glacier that once flowed out of the valley in the background

Alden from U.S.G.S.

break off into the sea. Rock material carried from the highlands is dropped or carried by glacial streams to still lower ground.

Such are the glaciers that creep down the sides of many high mountains on the earth today. They are powerful instruments of erosion, and they do much to change the expression on the earth's face. They are nothing, however, when compared with the glaciers of the Ice Age, which once covered some four million square miles of land in North America alone. These mightier ice sheets are gone but not forgotten, because they have left their marks in many places.

The Ice Age. The story of the Ice Age (or Glacial Period) begins about a million years ago, at a time when the climate all over the world began to get somewhat colder than it had been for several millions of years before. Glaciers gradually formed over the northern parts of both North America and Europe. They grew and grew until finally in North America they made a solid sheet of ice over all of what is now called Canada. Fingers of this ice sheet reached as far south as Long Island and New York City in the

During the Glacial Period the regions represented by the white areas on this map were covered with moving ice

East, and into southern Illinois in the Central States. The map on page 358 shows the area once covered by ice.

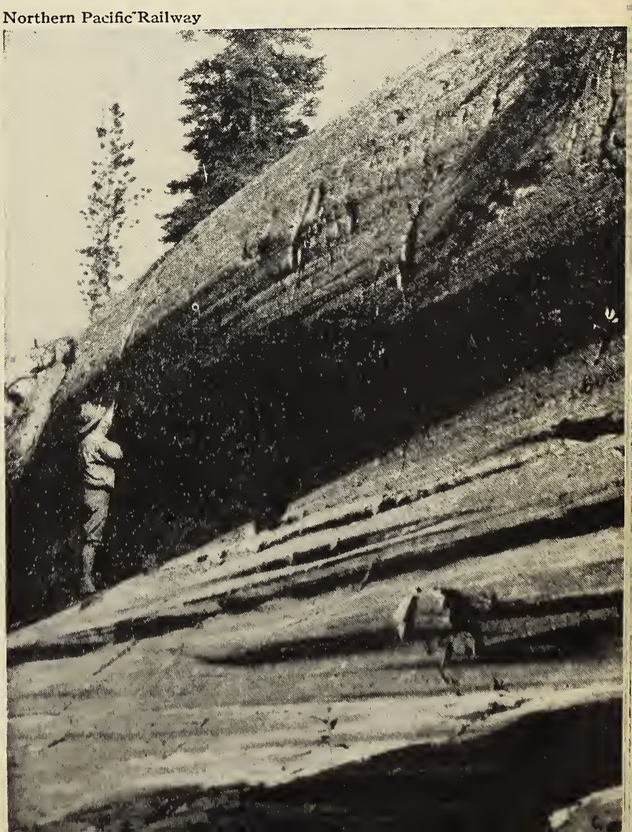
The glaciers of the Ice Age moved, but they moved very slowly. The most rapidly moving glaciers of today travel only a few feet in twenty-four hours. These ancient glaciers probably did not move more than a foot a day. At this rate they would have got over only about a hundred miles in fourteen hundred years. Perhaps they moved even more slowly than a foot a day. The main thing to remember is that the ancient glaciers *did* move and that this motion, though slow, developed a powerful force.

Glacial Erosion. As a glacier moves, loose boulders are picked up from the underlying and surrounding land. These are tightly frozen in the ice and pushed along the ground. The pressure, as you can imagine, is enormous. Ice Age glaciers must have been a mile or so thick, and must have exerted a pressure of more than three hundred thousand pounds on each square foot of ground.

Imagine a boulder slowly moved over a rocky surface with such a pressure upon it. It is easy to see that the boulder and the surface over which it moves would both be slowly ground

This great groove was gouged out of the rocks by a glacier

Northern Pacific Railway




Great Northern Railway

This lake lies in a valley which a moving glacier scooped out in a manner shown on the opposite pa

into tiny bits. Great grooves are thus gouged out of the rocky surfaces over which glaciers move (see page 359). In many places deep basins have been scooped out by moving ice and then filled with water when the glaciers melted away. The lake shown above was made in this fashion.

Glacial Deposits. After a time a glacier is carrying an enormous quantity of rock which it has picked up along its path. What happens to this material? We can find a good answer to this question by studying the vast regions which were once buried under the glaciers of the Ice Age.

When the climate began to get warmer at the close of the Ice Age, more snow melted in summer than fell in winter. The ice sheet accordingly began to shrink. How long did this process take? In one region where careful study has been made, it was found that the edge of the ice sheet retreated one hundred and eighty-five miles in about

A glacial valley is U-shaped because moving ice scours its channel both at the sides and the bottom. A river valley, on the other hand, is V-shaped because moving water erodes its channel chiefly at the bottom

forty-three hundred years. It is estimated that some thirty thousand years have passed since the ice began to leave the neighborhood of New York City.

The loose rock which had been carried by the ice was dropped when the ice disappeared. Some of the finer particles were widely scattered by the glacial streams. Glacial deposits of soil, sand, pebbles, and large boulders are therefore spread over the landscape wherever the ice sheets and their rivers once moved. In some places these deposits are several hundred feet thick. Any rock material which is laid down on the land by glaciers is known as *glacial drift.*

The Signs of Glacial Action. If you live or travel in a region that was once covered by glaciers, you can see plenty of signs of glacial action. You may find glacial scratches on the surfaces of rocks which were made when the ice

scraped along the ground. You may see great U-shaped valleys which the moving ice scooped out. Study the photograph and diagram on pages 360 and 361 for the explanation of how these valleys were formed.

You may also see large boulders which were dropped when a glacier vanished. You may see great deposits of sand and gravel and old stream beds now dry that once carried water from the melting ice. Do you see, then, that the surface of the earth has been greatly changed by moving ice and by the running water that formed when the ice melted?

Exercise. Study the map on page 358. Was the region in which you now live at one time under glacial ice? If so, see if you can find any proof of it in the rocks and soil of your locality.

We have now come to the end of our study of the forces of erosion. We have seen that though the changes produced by erosion take place very slowly, high mountains have been worn down and carried bit by bit to the sea during the millions of years of the earth's history. We have seen that the forces of erosion are still slowly but steadily wearing away the surface of the earth. In the next chapter we shall see that other forces deep inside the earth tend to build up the lands which erosion tends to tear down.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. The great changes which in the past have slowly torn down mountains as high as the Rockies have now practically stopped.

2. Though the force of freezing water has a marked

effect on loose soil, it is powerless to affect the stronger rocks of the earth.

3. The deposit of broken rock at the mouth of a river is known as talus.

4. Unless water is present in the cracks of rocks, temperature changes cannot break them.

5. Unless there are temperature changes, water in the cracks of rocks can do them no damage.

6. Hydrochloric acid is common in nature, and accounts for such great caverns as Mammoth Cave in Kentucky.

7. The stalagmites that hang from the ceilings of caves produce many strange and beautiful effects.

8. Though the wind carries a great amount of sand and dust which other forces have made, it has no power to break down rock itself.

9. Rivers are powerful carriers of mud and sand, but they cannot move large boulders.

10. Potholes are basins scooped out by glaciers and later filled with water.

11. The Amazon and the Mississippi are the greatest rivers on earth, and naturally have the largest deltas.

12. The Grand Canyon in the state of Colorado is one of the greatest examples of glacial erosion on earth.

13. The glaciers of the Ice Age made marked changes in the surface of North America because they were the most rapidly moving glaciers that ever existed.

14. When a glacier moves over a rocky surface, the surface is scratched or grooved by the ice.

Questions for Discussion

1. If you look at pictures of the Rocky Mountains in the West and the Appalachian Mountains in the East, you will see that the peaks of the former are sharp and rugged

while those of the latter are rounded and smooth. Does this tell you anything about the age of these mountains?

2. In what ways would the northern part of North America be different if it had never been covered by a great ice sheet? Take into consideration soil, agriculture, surface features, and drainage.

3. Which of all the forces mentioned in this chapter do you think has had most to do with changing the surface of the earth?

Things to Do

1. How well do you know your own locality? Are there any evidences of erosion there? Are there mountains near by? What do you know about their history? A well-planned field trip should give you many illustrations of the forces discussed in this chapter.

2. Take a number of photographs showing how natural forces are wearing down the surface of the land in your locality. Mount these pictures on a poster with appropriate explanations.

3. Every state has some scenic wonders which may be explained in terms of the story you have read in this chapter. What does your state have? Do you know its story? Perhaps you may want to write explanations of the scenic wonders in your locality or your state and present them in class. Many states have some kind of state department of geology. You may get help from this department.

4. Many of the regions set aside as national parks show evidence of forces that are wearing down the surface of the earth. See if you can find out anything about such regions and the forces that produced them.

5. Look up and report on the great glacier that covers most of Greenland today. How do you think this compares with the ice sheets of the past?

CHAPTER FOURTEEN

What Forces Are Building Up the Lands?

WHAT VOLCANOES DO TO THE EARTH

How Erosion Tends to Smooth the Earth's Surface. In the last chapter we studied what frost, changing temperature, acid water, rivers, and glaciers do to the surface of the lands. We learned how each one of these instruments of erosion tends to wear down the high places of the earth. In the process of wearing down the high places, however, erosion must fill in the low places. Rocks taken from the mountains by rivers and other agents of erosion are carried to lower and lower elevations and in time to the sea.

Do you see, then, that *by tearing down the high places and filling in the low places erosion tends to smooth the earth's surface*? If the forces of erosion should be allowed to work on unchecked, all the continents in time would be lowered to the level of the sea. The rock material carried from the lands to the sea would make the ocean water rise and flood over what was left of the continents. All land life would then disappear, and one great ocean would cover the entire earth.

Such a thing has never happened in the millions and millions of years since the earth began to record its history in the rocks. It has never happened—and probably never will happen—because forces deep inside the earth tend to build up what erosion tends to tear down. Let us see what these mysterious hidden forces are and how they manage to save the lands from destruction.

Shipvan from Sawders

This cone-shaped mountain in Peru is a typical volcano

Volcanoes. From time to time certain mountains on the surface of the earth throw out great quantities of gas, rock particles, and in some cases hot liquid rock which is known as *lava*. These mountains are called volcanoes. A typical volcano is shaped like a cone and has a saucer-like depression, or *crater*, at the summit, as shown in the photograph above. Volcanoes are among the most important instruments which build up the surface of the lands.

The History of "a Bad Fella." You have probably read about the volcano called Vesuvius. This volcano is in the southern part of Italy near the modern city of Naples (see the illustration on the opposite page). At the beginning of the Christian Era Vesuvius was thought to be dead (extinct). It towered quietly above the ancient towns of

Pompeii and Herculaneum, and was considered perfectly harmless because nobody had heard that it had ever erupted. A few people, however, knew that the volcano must once have been active because its top contained a well-developed crater.

The first disturbing suggestion that Vesuvius was not so quiet as it seemed came to the inhabitants of Pompeii in 63 A.D. The city and the surrounding country suffered a severe earthquake, which did great damage to houses and public buildings. The people immediately set to work to restore their property, but more earthquakes came. They kept coming off and on for sixteen years.

Then on a hot summer day in the August of 79 A.D., the earth began to tremble in a frightful manner. From the crater of Vesuvius steam, hot stones, and "ashes" began to belch forth. Half the crater was very soon blown away. Thousands of people were killed,—some suffocated by the gases and some crushed by the hot mud and "ashes." Others

The city of Naples has a treacherous neighbor in Vesuvius

Publishers' Photo

This house in Pompeii lay buried under loose volcanic rock for nearly seventeen hundred years

were trampled upon by the panic-stricken mobs as they rushed wildly about in the streets. In the end, Pompeii was completely buried in hot "ashes," Herculaneum in hot mud and lava. It was one of the worst tragedies in the history of man.

Little was known about these lost towns until nearly seventeen hundred years later, when a group of scientists decided to find Pompeii. The site of the town was located from historical records, and the work of digging was begun. Today you may walk through the streets of ancient Pompeii and see the rooms of houses just as they were almost two thousand years ago. There are paintings upon the walls and children's toys upon the floors. Dishes and food stand on dining tables where they stood when the residents ran

away in panic. As you look upon the pictures of these ruins in the picture on page 368, you realize that the landscape changed very suddenly for the unfortunate people who lived at the foot of Vesuvius in the summer of 79 A.D.

Time went on, and various less violent eruptions took place from the crater of the now active Vesuvius. Between eruptions the mountain seemed peaceful enough. Grass and trees had time to grow; Italian peasants who had never heard of the towns of Pompeii or Herculaneum had built homes at the foot of the volcano and had planted vineyards upon its sides. Then once again, in 1631, the earth began to rumble and tremble. This time there was a tremendous explosion, and treacherous Vesuvius again began to pour forth glowing streams of liquid rock.

The volcano has been more or less active ever since that time. Periods of a few years of quiet have been followed by periods of fresh activity, though no serious eruption has taken place since 1906. If you were in Naples tonight, you might see clouds of vapor rising from the crater, lighted by the intense heat from within. If you should climb to the crater's edge and look down into it, you would see a mass of liquid lava bubbling and spurting up, throwing stones and dust into the air. The guides from Naples point to the smoking crater of the mountain and say in broken English to the tourist, "He's a bad fella." Nobody who knows "his" history can disagree.

Other Volcanoes. Much of the land around Vesuvius shows signs of volcanic activity. Mount Etna is on the island of Sicily, about two hundred miles south of Vesuvius. During the period of its activity it has built a pile of lava and ashes which is now more than ten thousand feet high. Etna has been active from time to time for at least twenty-

Most active volcanoes of today are located in definite belts

six centuries. In the eruption of 1892 the lava that poured out of the crater was hot enough (1900° F.) to melt iron.

Stromboli is another Italian volcano. It stands on an island about a hundred and fifty miles from Vesuvius, between that volcano and Etna. It has been active since ancient times and has built up a mountain three thousand feet high. Violent eruptions are not common, but its activity is nearly continuous. Steam issues from the crater and then condenses and reflects the light of the glowing lava beneath. Because it is usually visible at night, Stromboli has been called since early times the "Lighthouse of the Mediterranean."

Italy is not the only place in the world that has volcanic activity today. There are active volcanoes in Alaska, Mexico, South America, Africa, Japan, Iceland, and on many of the Pacific islands. The United States has one active volcano, Mount Lassen, in California. Many of the highest mountain peaks in North America, including Shasta, Hood, Adams, Baker, and Rainier, are extinct volcanoes.

Exercise. See what you can find out about some of the famous volcanoes of the world, such as Mont Pelée, Mauna Loa, and Cotopaxi. Are they active now? Locate them on the map on page 370.

Zones of Volcanic Activity. The volcanoes of today are not scattered all over the earth but are limited to two rather well-marked zones. One of these zones surrounds the Pacific Ocean like a belt or girdle, and is sometimes called the "Girdle of Fire." Another less well-marked zone circles the earth through the Mediterranean Sea, Asia Minor, northern India, and the Philippines.

Exercise. Study the map on page 370, and observe the two chief zones of present-day volcanic activity. Are there any famous volcanoes that do not lie in these zones? If so, what are their names?

The Volcanic Activity of the Past. Though volcanoes today rather generally build cones which stand up conspicuously in the landscape, *the volcanoes of the past rather*

Mauna Loa in Hawaii is one of the mightiest active volcanoes of present times

Luke Field, 11th Photo Section, A.C.

generally did not build cones. They welled up through great cracks or fissures in the earth. In several countries immense flows of lava have formed level plains many thousands of square miles in extent.

If you should follow the Sunset Highway from Spokane to Seattle, Washington, you would never be off land that was built up by lava which flowed out of ancient fissures. In the Cascade Mountains the lava flows are piled up one upon another to a thickness of over three thousand feet. More than two hundred thousand square miles of Washington, Oregon, Idaho, and California are covered by these sheets of lava.

The Importance of Volcanic Activity. The great lava flows of the Northwest give us an idea of the tremendous power of volcanic activity to change the face of the earth. By bringing liquid rock from the inside to the outside of the earth, volcanic activity has been one of the chief ways by which the continents have been able to keep above the sea. Practically every part of the world has known volcanic activity at some time in its geologic history, so no forces have been more important in earth history than those which cause this activity. But just what are the forces which cause the movement of rock material from the inside to the outside of the earth?

EARTHQUAKES AND WHAT THEY TELL US ABOUT THE INSIDE OF THE EARTH

What Happens When the Earth Quakes. You may ask, "How can we know about the inside of the earth when we cannot get down there to study it?" The answer is that we can learn a great deal about the inside of the earth by studying the forces which first develop there and later make

Pictures, Inc.

A severe earthquake destroyed this city in a few minutes

themselves felt at the surface. We can learn about the inside of the earth particularly by studying the forces that produce earthquakes.

Anyone who has ever felt an earthquake knows how frightening an experience it is. The ground begins to grind and shake, tall buildings sway, chimneys crash into the street, women scream. If the quake is severe, gas and water mains are ripped apart, telephone and telegraph communication is stopped, houses jump off their foundations and collapse. Within a few minutes a community of thousands of people and hundreds of beautiful buildings may be ruined, as shown in the photograph above.

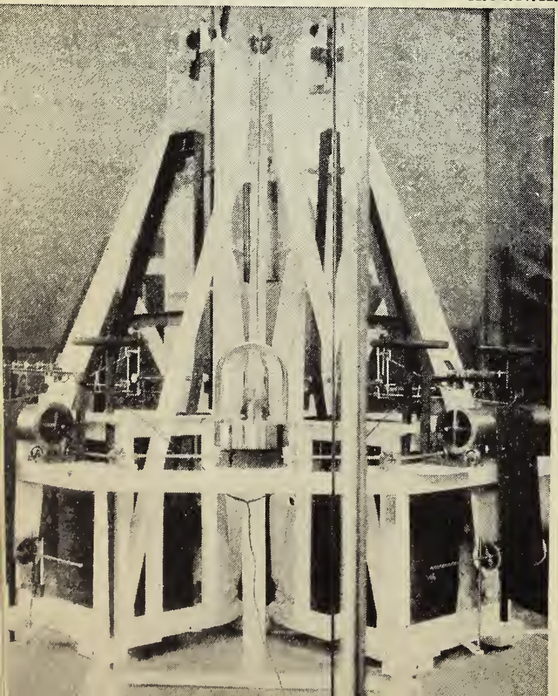
Exercise. Several disastrous quakes have shaken the earth since 1920. See if you can find out where these were, and make a report on them for your class.

How Earthquakes Are Recorded. Fortunately, disastrous earthquakes are rare. Quakes of less violence, however, are common, thousands of them taking place somewhere on earth every year. *Most earthquakes are so slight that they cannot be felt by the people in the regions that quake.* How, then, you may ask, can we know that such earthquakes take place? We can know it because a very clever instrument, the seismograph, tells us so.

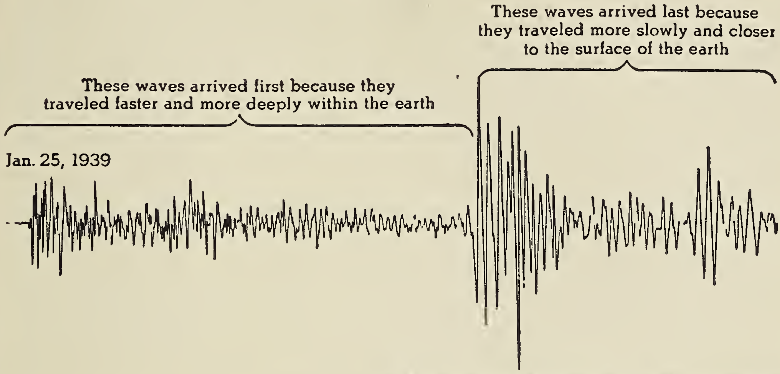
Seismographs ("earthquake-recorders") are in operation in many different places all over the world. In its simplest form a seismograph consists of two parts: a heavy pendulum so hung that it tends to remain still even when the earth trembles; and a base which is anchored in solid rock. The illustration below shows one of these instruments.

During an earthquake the base of the seismograph moves with the rock in which it is anchored. On the base is mounted a cylinder, or drum, which is turned by clockwork. As it turns, a pen connected to the pendulum draws a line on the surface of the paper that covers the drum. If there are no earth movements, the line drawn by the pen is straight. If, on the other hand, the earth quakes, the shocks are passed through the base to the drum and paper. The result is a jagged line, as illustrated on the opposite

Seismographs detect and record the shocks produced by earthquakes
A.M.N.H.



page. Notice how the straight line suddenly gave way to a jagged line as the instrument recorded the earthquake.



Oak Ridge Seismograph Station, Harvard University

This is the record of an earthquake in Chile as made by the seismograph at Harvard University. The earth vibrations indicated by the jagged line lasted seventeen minutes

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What Earthquakes Do to the Earth. During earthquakes many changes take place in the earth's outer crust. Some regions may be raised and others lowered along cracks that have developed in the rocks. Cracks along which masses of rocks have shifted their positions are called faults. *Nearly all earthquakes are caused by the sudden slipping of blocks of the earth's crust along faults.* The photograph on page 376 shows how the rocks are pulled apart along a fault.

Where Earthquakes Occur. Where violent earthquakes are common, high mountains and deep oceans are usually close together. One of the deepest places in the ocean is just off the shore of Japan, and eastern Japan is the scene of frequent earthquakes. Many earthquakes occur in regions of present or recent volcanic activity. Indeed, the two zones of volcanic activity are also zones where earth-

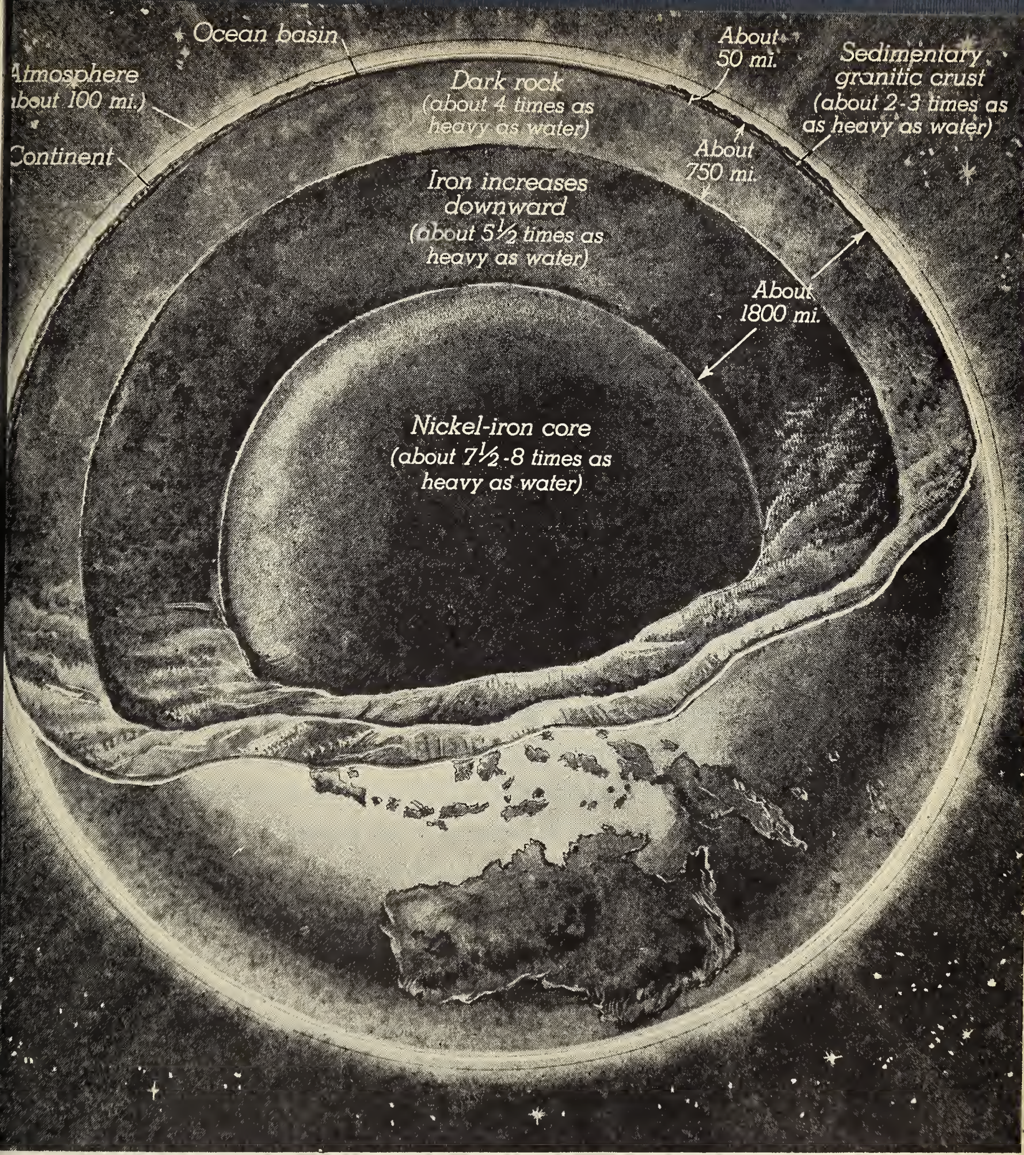
quakes are common. Why do volcanoes and earthquakes flock together?

The Body of the Earth. Before we attempt to answer this question, let us see what earthquakes tell us about the interior of the earth. When rocks suddenly shift their positions along a fault, the tremors, or shocks, travel through the earth as waves in every direction. It has been learned that these waves travel faster through the deeper parts of the earth than along the surface. They are thought to do so because the inside of the earth is more stiff, or rigid, than the surface crust. Earthquake vibrations are like the vibrations in a bell. A bell of clay will not ring because it will not vibrate. The deep interior of the earth acts like a bell of steel.

Other facts lead to the belief that the body of the earth behaves like steel. It is known that *the earth as a whole* is about 5.5 times as heavy as an equal volume of water. *The surface rocks*, on the other hand, are only about 2.7

The slipping of blocks of rock along cracks (left) is the most common cause of earthquakes. Shifting of the ground during an earthquake made the gap in the fence at the right

U. S. G. S. Gilbert from U. S. G. S.



The materials that make up the earth grow heavier from the surface toward the center. The zones of different materials are set off sharply from one another in this diagram so that you may better understand what they are. In the earth they probably change gradually from one to the other

times as heavy as an equal volume of water. Do you see, then, that the material of *the earth's core* must be more than 5.5 times as heavy as an equal volume of water in

order to balance the lighter material in the outer crust? Nobody knows whether the central core is made heavy by the great pressure of the crust on ordinary rock material, or whether heavier minerals exist in abundance there. Many scientists believe that the core is made largely of iron, which is 7.7 times as heavy as water.

The Zones of the Earth's Interior. What would a cross section of the earth look like, according to this belief? Study the diagram on page 377. Most of the surface of the earth is covered with rocks formed from the deposits of sediments which were laid down in the shallow seas that frequently took form on the lands of the past. Beneath these so-called *sedimentary rocks* are rocks which cooled and hardened from a liquid condition. These are the *igneous* ("*fiery*") *rocks*. In some places, where the covering of sedimentary rock has been removed by erosion, some form of igneous rock, generally granite, lies at the surface.

Beneath the sedimentary and granitic crust a thick layer of dark rock is thought to exist. This material comes to the surface as lava flows in many places, and is called basalt. It is a little heavier than the ordinary surface sedimentary rocks and granites because it contains a little more iron. Farther down, iron is believed to become more and more abundant. At a depth of a thousand miles the rocks contain a very large amount of this metal. The core of the earth, as we have seen, is believed to be made of iron or of iron combined with nickel.

The Temperature of the Earth's Interior. With this picture in mind let us consider another question. Is the interior of the earth hot or cold? Much evidence points to the fact that it is very hot. Mine workers are well aware that the temperature in deep mines is higher than the temperature

at the surface. In the copper mines of Michigan and in some of the gold mines of South Africa, the heat is extremely uncomfortable. From this and other evidence scientists estimate that the average increase in temperature is about 1° F. for every sixty feet in depth. Can you see that if this rate continues downward the earth must grow very hot toward the center?

Is the interior of the earth, then, a liquid? The temperatures deep within the globe would certainly seem to be far above the melting point of rock. Many scientists, however, believe that *even though the rocks of the interior are hot enough to melt under surface conditions, they are kept solid by the tremendous pressures which are produced by the weight of the rocks in the outer crust.*

All these facts can now be put together. If for any reason the pressure at the surface of the earth is reduced, the hot rock material in the interior moves toward the outer crust. If there are cracks in the solid rocks above, the hot liquid rock material underneath may flow up toward the surface.

Volcanoes lie in zones of weakness in the earth's crust, where rocky material is frequently broken and shifted around. This breaking and shifting of the rocks also causes most earthquakes. Do you see, then, that volcanoes and earthquakes flock together because they both result from the same weakness in the body of the earth?

Exercise. People of long ago knew little about the processes going on within the earth. They explained these processes as the acts of certain gods. Prepare a class report on some of these ancient beliefs. As a beginning, look in some book of myths for information on Vulcan and the Titans.

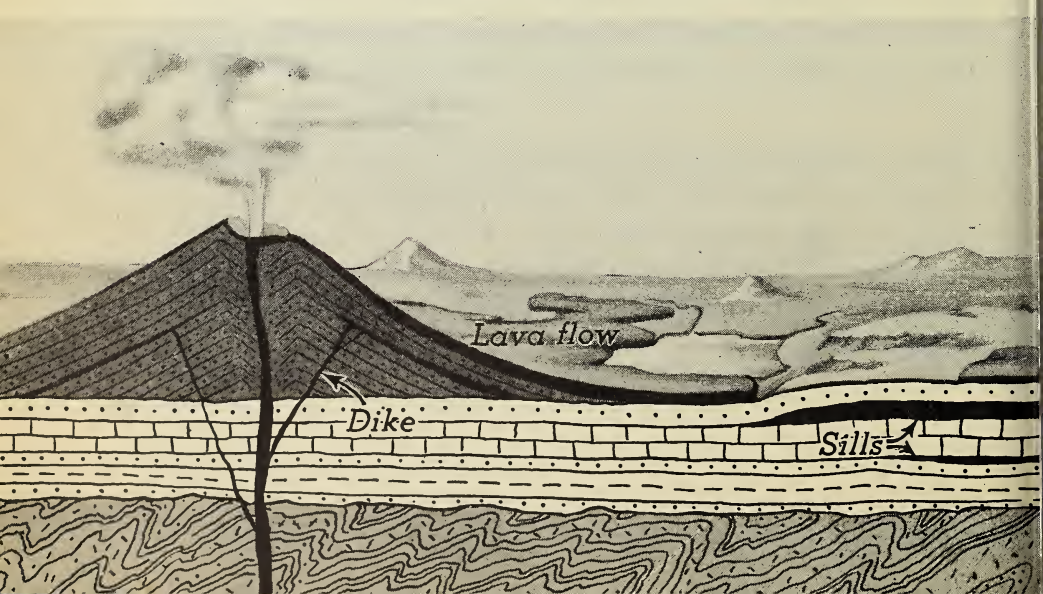
HOW THE SURFACE OF THE EARTH IS WRINKLED

How Mountains Are Built. If you have ever traveled across a chain of high mountains, you have probably wondered how it was formed. If all mountain peaks were volcanic in origin, you could decide that the peaks were carved by erosion from lava and volcanic ash. Unfortunately great mountain chains are not so simple as that. The Rockies, the Appalachians, the Himalayas, and other mighty mountain systems are not volcanic in origin. They were formed when the rocks of the earth's crust were squeezed into great wrinkles, or *folds*.

Study the diagrams below and on the opposite page. Notice that one is a cross section through a typical volcano and the other a cross section through a typical mountain range. Can you see any differences? Notice that the volcano is built on flat rocks and that the mountain range is carved out of folded and faulted rocks. How does the surface of the earth become wrinkled?

Have you ever seen an apple that had been kept in the cellar all winter? Such an apple is dry and shriveled. As

The typical volcano is built on flat rocks



The typical mountain range is carved out of folded rocks

moisture evaporated from it, its core shrank and its skin became too big for it. The result was that the skin was thrown into wrinkles and cracked.

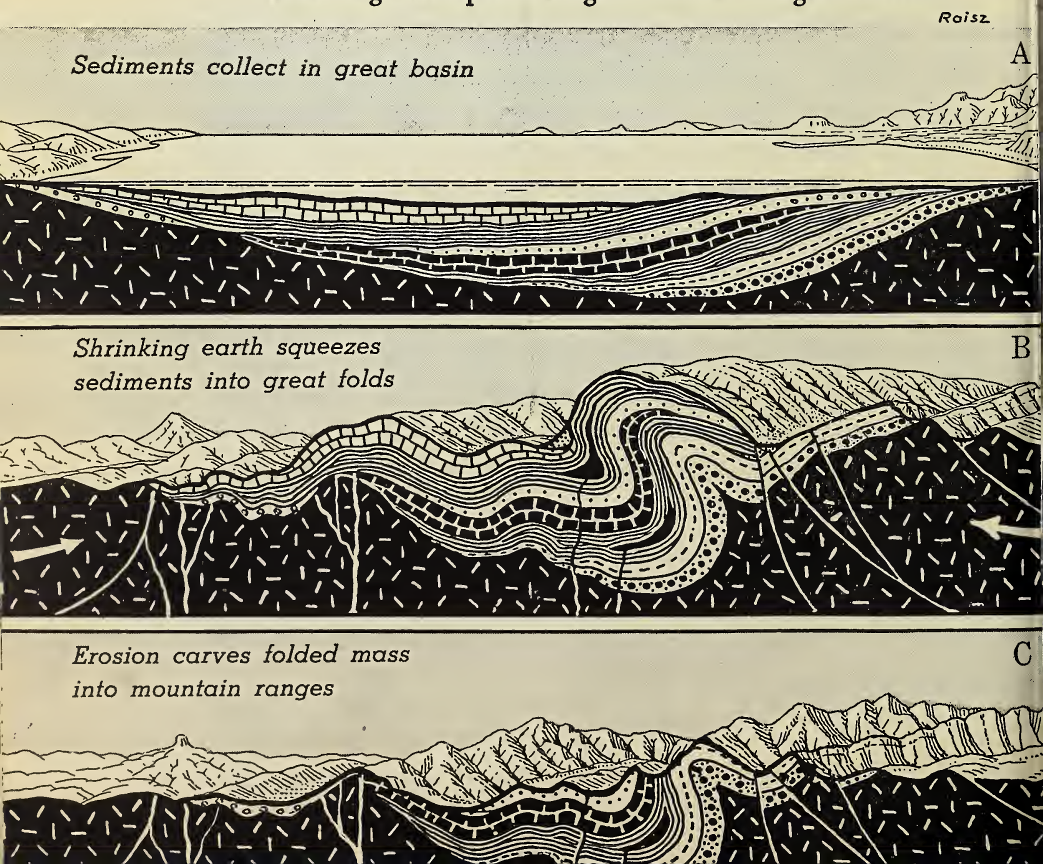
Many geologists believe that great mountain chains may have been formed in somewhat the same way. They believe that the earth has been losing heat and shrinking for millions of years. They believe that the "skin" of the earth is thrown into wrinkles of mountain chains so that it may continue to fit tightly around the shrinking "core."

Study the series of diagrams on page 382, which illustrates how mountains are built. Notice that in A sediments have collected in a great trough similar to the present San Joaquin Valley in California. Due to the weight of these sediments, the trough becomes a weak zone in the earth's crust. When finally the earth gives way to the forces of shrinkage, the sediments are squeezed into folds, as shown in B. Liquid rock oozes up from below and hardens in the cracks which the folding has produced. Later, as shown in C, erosion carves the uplifted mass into a mountain chain.

Though not all mountain chains have been formed in this fashion, the greatest ones undoubtedly have. They represent zones in the earth's crust which have been squeezed from side to side. As you travel through the mountains you may see signs of this squeezing wherever you go. In many places wrinkles and cracks occur in the layers of the sedimentary rocks. It is clear that such rocks must have been flat when they were formed, but in the mountains you may see them folded at steep angles (see photograph on the opposite page).

As folding takes place, cracks, or faults, are formed. These, as we have seen, offer channels through which the liquid rock material from far below may flow up toward the surface. When such material hardens in a crack that cuts *across* layers of sedimentary rock, it is called a *dike*.

These diagrams explain how great mountain ranges are built



U. S. G. S.
This mountain peak was carved from layers of rock which once were flat

When such material hardens *between* the layers of sedimentary rock, it is called a *sill*. You can find these formations in the illustrations on page 384.

Granite is a speckled igneous rock that hardens from the liquid to the solid condition below the surface of the earth. It appears on the surface, however, in many mountainous regions where the cover has been worn away by erosion. Pikes Peak and many other high mountains are masses of granite which have been pushed up from beneath. The sedimentary rock that once covered Pikes Peak was softer than the granite, and has long since been worn away.

The Story of the Rockies. In view of all this, you will realize that a mountainous region is one that has undergone enormous changes. Consider the present Rocky

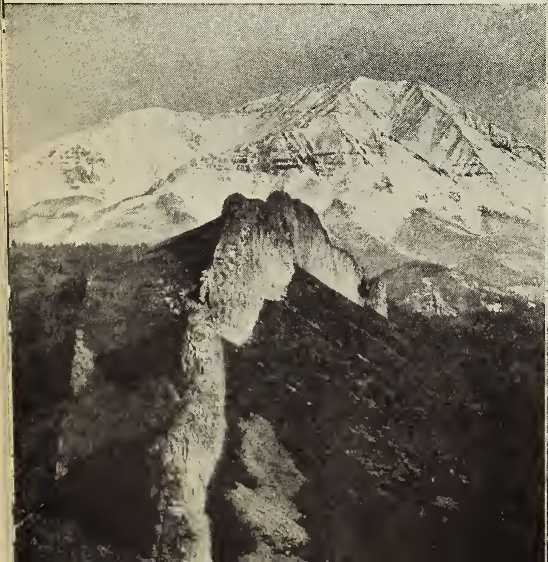
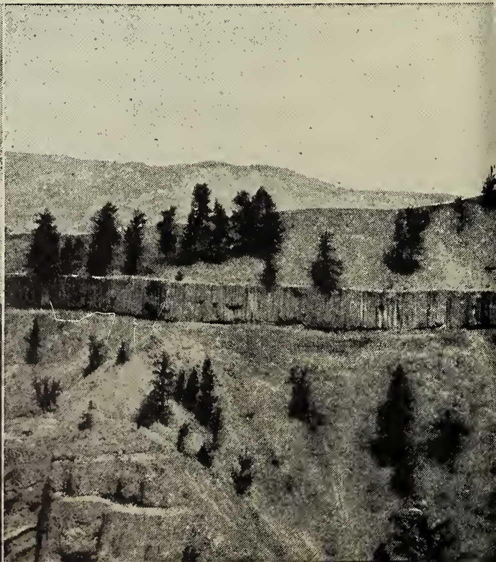
Mountains. At one time this area was an arm of the sea. Thick layers of sediment were dumped into a mighty trough by rivers which drained the higher surrounding lands. These sediments were slowly hardened into layers of shale, sandstone, limestone, and other kinds of rock.

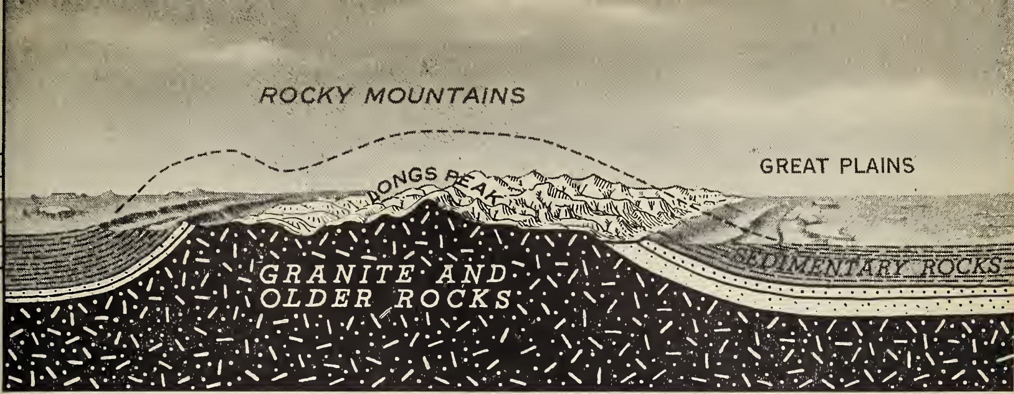
In the course of geologic time, unequal pressures within the earth raised this region until it was above the level of the sea. Continued pressure raised the surface higher and higher, and folded and faulted the rocks. Remember, however, that these changes took place so slowly that they could not have been noticed—even if there had been people there to notice them.

A cross section through Longs Peak, in the Rockies, shows how the sedimentary rocks there have been worn away from the top of the peak. Longs Peak is now more than fourteen thousand feet high. The broken line in the diagram at the top of the opposite page shows that it would have been at least twenty-five thousand feet high if the forces of erosion had not worn the top away. As you look at this mountain you see evidence of enormously complex changes, changes which are still going on.

The dike at the left cut across layers of rock when it moved toward the surface as a liquid mass. The sill at the right squeezed between flat layers of rock

U. S. G. S.

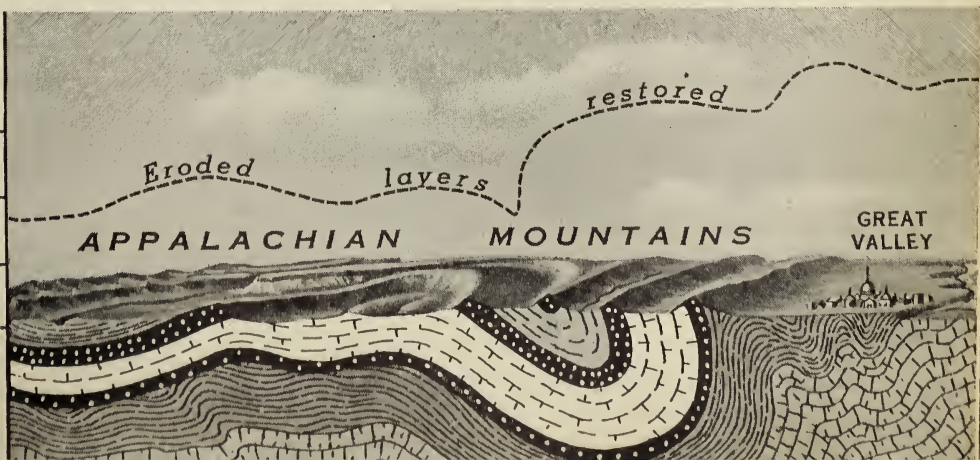


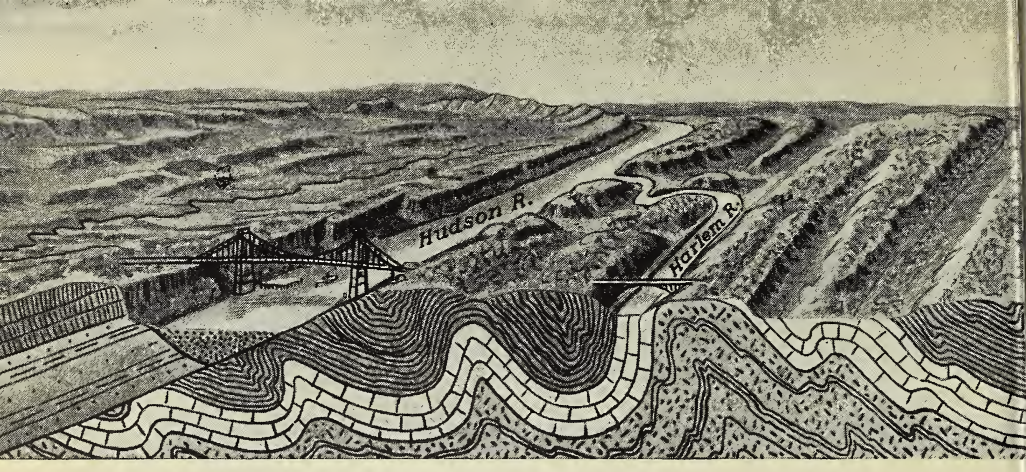
osion has stripped the sedimentary rocks from Longs Peak in the Colorado Rockies

The Appalachians. A cross section through the Appalachian Mountains is given below. This shows how these mountains, too, were formed by the folding of sedimentary rock, and how the tops of the mountains have been worn away. The Appalachians, however, are much older than the Rockies. Study the diagrams above and below together, and see if you can find any proof of this fact.

The Vanished Mountains of New York City. There is evidence that the region around New York City was once a place of high mountains. The diagram on page 386 shows a cross section through the island of Manhattan and near-by territory, on which part of New York City is built. Today

he Appalachian Mountains are made of folded sedimentary rocks which have been greatly worn down by erosion





The rocks in the region of New York City are the worn-down stumps of once mighty mountain

nothing but the bases of the ancient mountains remain. The peaks have been worn down nearly to the level of the sea, chiefly by the attacks of rain and running water during countless ages of time.

Where to Look for Proof of Earth Changes. Perhaps after reading this chapter you may feel that evidence of earth changes can be found only by someone highly trained in geology. This, however, is not true. With the knowledge you now have you can find many illustrations of the forces we have studied in this chapter. You can probably find them within easy walking distance of your own home.

If you live in a flat region you can still find such illustrations. Banks of rivers may be cut away, showing a cross section of layers of sedimentary rock. Even in the city you may find proof of earth changes. Have you ever watched men working on the foundation of a large building as it was sunk into the ground? Frequently, after a few feet of earth are removed, masses of solid rock appear. In the sides of these excavations you may find convincing proof of the play of powerful forces.

Exercise. Is there any evidence in your locality of the elevation of the earth? Are there any rocks, such as those shown below, that were certainly at one time beneath the sea? These questions and others may be answered by information gathered on a well-planned field trip. The results might be organized in a class exhibit on "The Geologic History of Our Region."

THE AGE OF THE EARTH

The Earth Is Very Old. All through this unit we have seen that great changes in the landscape have been taking place. But how long have these changes been going on? How old is the earth?

Nobody can answer these questions exactly in terms of years. The year is a good measure for relatively short periods of time, but it is much too short a measure for the vast periods of earth history. There are ways, however, of measuring geologic time and of interpreting it in a general way in terms of years. Let us examine these methods briefly in this section.

What Rivers Tell Us. You have seen that though rivers work very slowly they tend in time to wear down the

The hardened ripple marks of ancient sea bottoms (left) and the fossil shells of creatures long dead (right) tell of mighty changes in the earth

U.S.G.S.

roughest lands. You might spend your entire life on the banks of a river without seeing any noticeable widening of the valley. Rivers, however, do widen their valleys, but at a very slow rate compared with the length of a human life.

At St. Louis, for example, the hills on either side of the Mississippi River are about twenty miles apart. At one time the Mississippi was a young river, and its valley walls were close together. Geologists have estimated on the basis of the present rate of erosion that it took this river about a million years to cut its valley to its present width.

If general conditions remain the same in the future as they are today, the valley of the Mississippi will get wider and wider. The river and its tributaries will slowly wear the entire area over which they flow toward flatness. This process of flattening, *which geologists know has taken place over and over again in the history of the earth*, must require tens of millions of years. Do you see, then, that rivers tell us that the earth is very old, perhaps hundreds of millions of years?

What Sedimentary Rocks Tell Us. We have seen that sedimentary rocks have been laid down in layers on the continents from time to time in shallow arms of the sea. If all these layers could be gathered together in one place, they would make a pile some sixty-five miles high! Nobody knows how fast these rocks were laid down as sediments. Studying the rate at which similar sediments are being formed today at the mouths of rivers, it is clear that they were laid down very slowly. To build up sixty-five miles of sedimentary rocks, millions—perhaps hundreds of millions—of years were needed.

Charles Phelps Cushing

As the Cascade Mountains rose, the Columbia River cut into them without being thrown from its course

What Mountains Tell Us. We have already seen some evidence of the fact that mountains are built very slowly. Perhaps the most striking evidence of this lies in the history of the Cascade Mountains. Geologists know that the Columbia River was flowing across the state of Oregon before the Cascades were uplifted. As the mountains rose, the river cut into them without being thrown from its course. Today it flows right through the heart of the range. We know that rivers cut into their beds very slowly; so the Cascade Mountains must have risen very slowly in order not to throw the Columbia out of its course.

Furthermore, we have seen that New York City is built on the worn-down stumps of old mountains; that repeatedly mountains have been built and destroyed during the course of earth history. Since mountains are both built

UNKNOWN
At least 60 million years ago
At least 200 million years ago
PALEOZOIC
At least 500 million years ago
PROTEROZOIC
At least 1 billion years ago
ARCHEOZOIC
At least 2 billion years ago
UNKNOWN


FUTURE
CENOZOIC
MESOZOIC
PAST

and torn down with extreme slowness, do you see that they speak of a very ancient earth?

What the Oceans Tell Us. The oceans also speak of the great antiquity of the earth. Geologists believe that in the beginning the oceans were fresh; that their salt was slowly carried to them in streams from the land. By dividing the estimated amount of salt in the oceans by the estimated rate at which rivers are carrying in salt today, we can find out how much time was necessary to bring the seas to their present state of saltiness.

By this method geologists have found that it must have taken at least one hundred million years for the rivers to do this job *at their present rate of work*. There is good reason for believing, however, that rivers are working faster now than ever before. Today the lands stand higher above the sea than did most of the lands of the past. The result is that modern rivers flow more rapidly than did ancient rivers and carry more material to the sea. Do you see, then, that it must have taken more than one hundred million years—probably several hundred million years—for the rivers to bring the oceans to their present degree of saltiness?

What the Unstable Elements Tell Us. Experiments by physicists and chemists have shown that a few rare elements in the earth are constantly breaking down. Uranium is such an element. It passes slowly through many stages (radium being one of them), and finally ends as helium (a gas) and lead (a solid). The speed of these changes cannot be changed and is accurately known by experiment.

If a rock contains uranium, and lead which came from uranium, scientists can estimate how old the rock is by

estimating how long it took to produce the lead. By this method, the oldest known rock in the earth's crust has been found to have the tremendous age of one billion six hundred million years!

How the Geologist Deals with Time. In view of the great age of the earth, it is clearly impossible for the geologist to date events in earth history as accurately as the historian dates events in human history. The geologist, indeed, is interested more in *the order of events* than in the exact dates of their happening.

The geologist can recognize great eras which followed one another in the history of the earth. Like the historian who divides human history into ancient, medieval, and modern, the geologist divides earth history into certain large divisions. The chart on pages 390 and 391 will give you an idea of what happened to the earth during each of these eras of time. In the next chapter we shall study the strange creatures that lived during those distant days.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. By tearing down the lands and filling in the ocean basins, erosion in time will make the earth's surface perfectly smooth.

2. Dust blown out of a volcano is known as lava.

3. The United States is lucky in having no active volcano.

4. The chief zone of volcanic activity is the "Girdle of Fire" which surrounds the Atlantic Ocean like a belt.

5. The volcanoes of the past, like modern volcanoes, erupted through craters in the tops of cone-shaped mountains.

6. A seismograph is an instrument for measuring the heat of the lava in a volcanic crater.

7. All earthquakes are caused by volcanic eruptions.

8. Scientists know that the outer crust of the earth is much heavier than the inner core.

9. The interior of the earth is thought to be cold because the deeper we go in a mine the colder it becomes.

10. Most mountain chains are volcanic in origin.

11. The Rocky Mountains are not so high as they once were because the rocks have settled considerably since they were folded and uplifted.

12. Earth changes have taken place everywhere, but only the trained geologist can recognize them.

13. The geologist has no way of telling the age of the earth because the year is too short a measure for geologic time.

Questions for Discussion

1. What is meant by the statement that every rock carries within itself evidence of the conditions under which it was formed?

2. Do you think that rocks are being formed today? How? Does this tend to raise or lower the surface of the earth?

3. Why are the earthquakes in North America so much more severe on the western coast than on the eastern coast?

4. Which do you think is the more rapid process, the raising or the lowering of the surface of the earth? Why?

Things to Do

1. Find out from your state geologist whether a geological survey has been made of the region in which you live. If such a survey has been made, you may be able to get from the United States Geological Survey, Washington, D. C., a geological map showing conditions of your locality or of some place near you.

2. Make models or exhibits from clay or modeling wax to show one or more of the following:

a. Formation of mountains by folding
b. A fault
c. A cross section of a volcano
d. Several sedimentary rock layers
e. A lava flow
f. Dikes and sills

3. Prepare a wall chart showing a cross section of the earth through the equator. Indicate the different layers and their supposed composition.

4. Some fascinating travel books have been written about the earth. You would probably enjoy *First through the Grand Canyon*, by J. W. Powell; *The Valley of Ten Thousand Smokes*, by R. F. Griggs; *Living Africa*, by Bailey Willis.

CHAPTER FIFTEEN

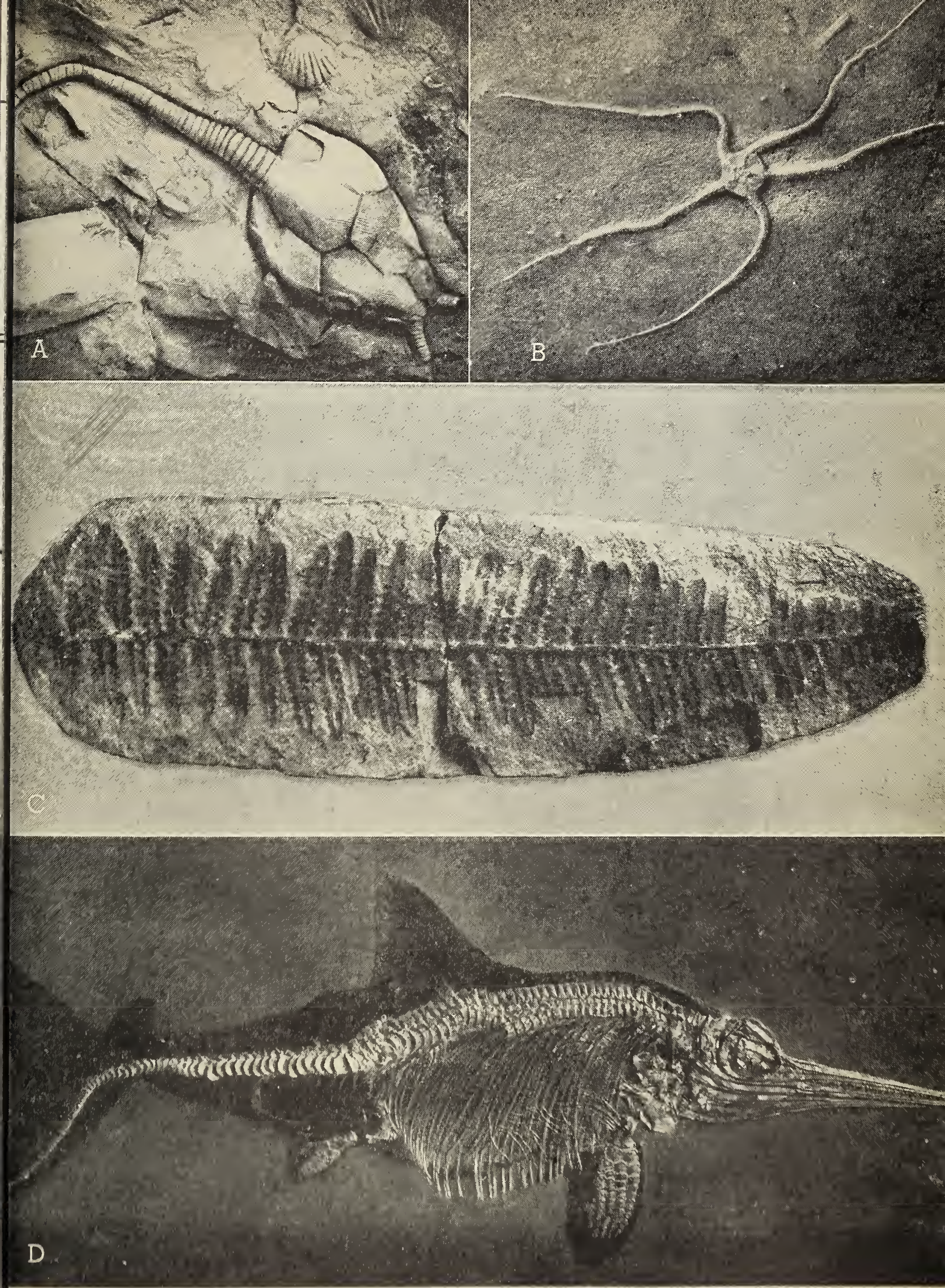
What Kinds of Plants and Animals Lived in the Past?

HOW SCIENTISTS READ THE STORY OF ANCIENT LIFE

Tales Told by the Dead. There is an old saying that "dead men tell no tales." It seems clear enough that the dead cannot speak either truth or falsehood. There are ways, however, of finding out about the dead, even though they have not been alive for a long, long time. There are ways of making the creatures of a far-distant past give up the stories of their lives. But just how can we make these dead bones talk? This is a good question, for which science has an equally good answer.

If you have ever worked in the garden, your spade has probably turned up many things: pieces of broken bottles, tin cans, earthworms, chunks of wood, stems of plants, perhaps the skeleton of a bird or other animal. At the time of digging, these things probably annoyed you because they made your job just that much harder. If you think over the experience, however, you will realize that this garden rubbish contained evidence of life that existed months and perhaps even years ago.

In the same way scientists have dug into the layers of rock which took form during the different eras of geologic time. They have turned up evidence of a much more ancient life than that which is preserved in your garden. As we saw in the last chapter, scientists can estimate in a general way how long ago the different layers of rock were



A. M. N. H.

Fossil shells (A and B), leaves (C), and bones (D) help to tell the story of ancient life

formed. In the same way they can know about when the creatures lived whose remains are preserved in the different layers. By studying these remains they can learn about the appearance and habits of the creatures which the remains once were.

Fossils. Perhaps you have seen fossils buried in solid rock. *Any trace of a living thing preserved in rock is called a fossil.* Three kinds of fossils are shown on page 397. From what you know about the formation of the sedimentary rocks you can probably guess how the fossils got there.

Animals that occupied such shells as are shown at A and B on page 397 once lived in mud on the bottom of the sea. In the course of time the animals died and the mud hardened to stone. The outlines of the shells, and in some cases the shells themselves, were preserved in the hardened mud. In the same way the bones of larger animals and the remains of plants (see D and C) have been caught in mud or sand which later turned to stone. By the study of such fossils we may get a good idea of the kinds of animals and plants that lived on the earth during many long ages of the past.

A trained geologist can tell, from the way in which the layers of sedimentary rock rest upon one another, which are older and which are younger layers. The older rocks lie underneath the younger rocks. Obviously the fossils of plants and animals which lived longest ago are found in the oldest rocks. The fossils of creatures that lived more recently are found in rocks which took form at a later date. Where such rivers as the Colorado have cut down into the older rocks, and where mountain-building movements have brought the older formations to the surface of the earth, fossil specimens of very ancient life may be collected.

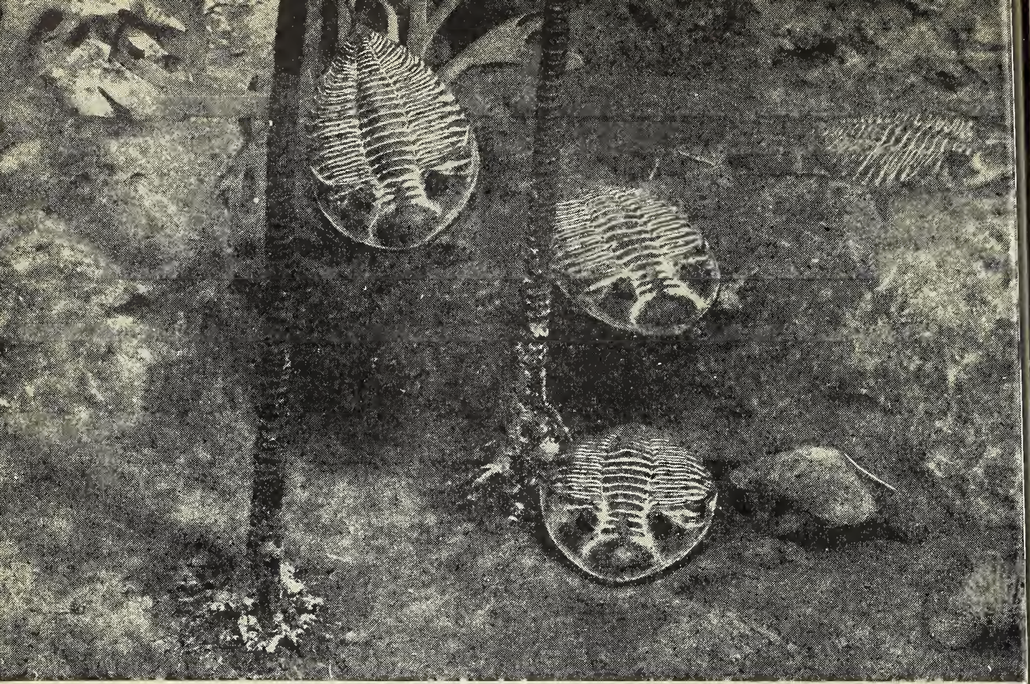
Exercises. Roy Chapman Andrews is one of the best-known modern fossil-hunters. See if you can find any of his stories. One place to look for them is in the *National Geographic Magazine.*

If layered sedimentary rocks occur in the quarries and road cuts of your locality, it may be possible for you to make a collection of fossils. Information about possible fossils in the rocks around your home can be obtained from your state geologist. Try to identify the fossils which you are able to collect, and arrange them neatly for display. You may wish to write to boys and girls in other localities and offer to exchange some of your fossils for some of theirs.

THE CREATURES THAT LIVED BEFORE MAN

Life of the Archeozoic Era. If you turn back to the chart on pages 390–391, you will find that the oldest rocks as yet discovered were formed during the Archeozoic era. Erosion has stripped the younger rocks off the top of these ancient formations in many places, and geologists have been able to examine them for the remains of ancient life. Though hundreds of people have searched and searched for fossils in the Archeozoic rocks, practically no remains of living creatures have been found there. Does this mean that there was practically no life on earth during some half a billion years of its history?

The answer to this question is No. Though the Archeozoic was a time of great disturbance in the crust of the earth, conditions were doubtless not wholly unfavorable for living creatures. The remains of plants and animals that lived at that time were probably changed so much in the heat and pressure which were produced by movements in the earth that they cannot today be recognized.


Buffalo Museum of Science

Can you see why the trilobites which swarmed in the seas of the Paleozoic era got their name?

The pencils which you use in your school work are made of a black material which is called "lead" but which is really the mineral graphite. Much graphite is mined in rocks of Archeozoic age. Because graphite is carbon, a material which is common in the bodies of plants and animals, many geologists believe that the graphite deposits of the Archeozoic were formed from the squeezed and heated remains of living creatures.

Life of the Proterozoic Era. Though the Proterozoic era was not so disturbed as the earlier Archeozoic, it too has left few tokens of the life that lived during its distant days. It is possible that during both the Archeozoic and Proterozoic eras plants and animals rather generally were small, soft, and easily destroyed. Some fossils, however, have been found in Proterozoic rocks, enough to prove that life was

undoubtedly on the earth at that time. Primitive seaweeds, single-celled animals, sponges, and worms have been dug up in various places.

Life of the Paleozoic Era. With the coming of the Paleozoic, third era of geologic time, the earth changed very noticeably. Earth movements became fewer and less intense; warm, shallow seas, like Hudson Bay, crept back and forth over the surface of the continents. These seas were swarming with life, chiefly simple shellfish of many varieties. The most interesting of these was the *trilobite* ("three lobes" or "three parts"), an ancient ancestor of lobsters and crabs. Some of these creatures are shown on the opposite page, surrounded by some of their neighbors.

[1]Adapted from Williston, *Water Reptiles of the Past and Present*, The University of Chicago Press.

Life was well established on land toward the close of the Paleozoic era[1]

Buffalo Museum of Science

This monster ruled the seas of the middle Paleozoic era

Early in the Paleozoic era fishes came to the seas, probably from the rivers of the land. Most of these fishes were heavily armored and some of them were strong and swift. The illustration at the left shows one of the fiercest of Paleozoic fishes. Imagine what would happen to a trilobite that started an argument with such a monster!

Exercise. Do you think there were any differences between the kinds of fishes and other water animals that lived during the Paleozoic era and those that are living today? What differences do you think there might have been? Where should you go to find out?

Toward the close of the Paleozoic era, land life became more and more abundant. Great forests, such as the one

This is a model of *Brontosaurus*, the largest land animal that ever lived

James Sawders

shown on page 401, stood on many swampy lands and supplied the material out of which our richest coal deposits were made. The earliest four-footed animals—amphibians and reptiles—lived in these forests, and in the air were some of the earliest insects.

Exercise. One of the best books on ancient plant life is *Plants of the Past*, by F. H. Knowlton. Read the account of Paleozoic plants in this book and make a report for your class on how Paleozoic plants differed from modern plants.

Life of the Mesozoic Era. The Mesozoic, or "middle life," era of geologic time is sometimes called the Age of Reptiles. The commonest and most interesting reptiles of this era were the dinosaurs. Though some of them were no larger than chickens, others were the largest land animals that ever lived.

One of the largest, the *Brontosaurus*, weighed nearly forty tons! It was five or six times as heavy as the largest elephant that ever lived and many times larger than a man,

Heavyweight bouts must have been common during the Mesozoic era. This one featured *Triceratops* on the left and *Allosaurus* on the right

A. M. N. H. Roland Bird, A. M. N. H.

The fossil eggs and footprints of dinosaurs help scientists understand the habits of those strange Mesozoic reptiles

as you can see in the picture on page 402. Such an animal probably needed an enormous amount of food. The warm, moist climate of most of the Mesozoic era was favorable to the growth of water plants, which these dinosaurs ate.

The smaller *Allosaurus*, pictured on page 403, was a flesh-eating dinosaur, as his sharp teeth prove. The large but awkward *Brontosaurus* was probably helpless when attacked by the *Allosaurus*. Indeed, there is very good evidence that this larger animal was food for the smaller one; for their bones have been found together, with those of the larger one partly destroyed.

Fossil dinosaurs are found in many places. The members of a scientific expedition to The Gobi, a desert in Asia, recently found many of them. Among other things they found fossil dinosaur eggs which are now on exhibition in

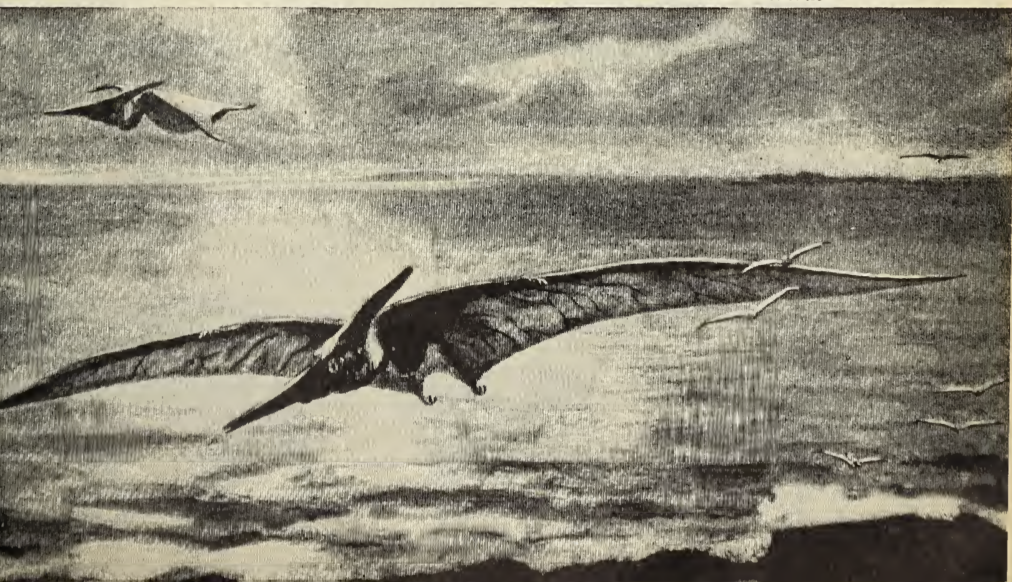
the American Museum of Natural History in New York (see opposite page). In North America dinosaur bones occur abundantly in the Mesozoic rocks of Wyoming and Montana. Dinosaur footprints are common in the rocks of the Connecticut valley in New England and in certain other regions. The photograph on page 404 is a sample of such footprints.

The age of the dinosaurs came to an end at the close of the Mesozoic era. Rocks formed since that time show no traces of them. It is believed that they lived in the warm swamps that covered much of North America during this era. As the era drew to a close, the land became higher and the climate became drier and colder. The dinosaurs were poorly adapted to dryness and cold and to the lack of abundant food which dryness and cold bring about. They disappeared without leaving a single descendant.

Exercise. Two of the dinosaurs named in this chapter are the *Brontosaurus* and the *Allosaurus*. There were many others, including the *Tyrannosaurus*, the *Triceratops*, the *Diplodocus*, and the *Stegosaurus*. Though the names

These creatures look like birds, but they are really flying reptiles

Smithsonian Institution

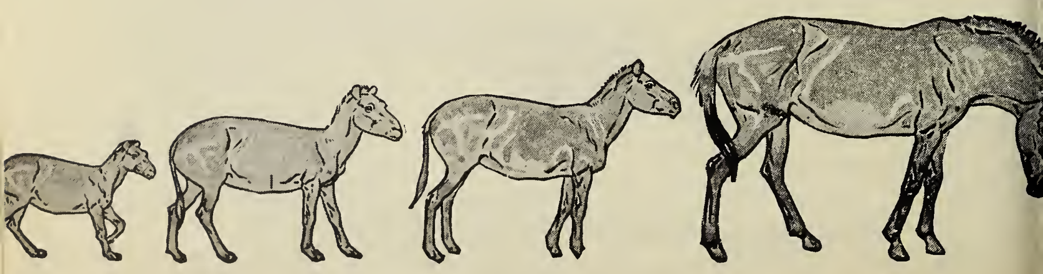


of these creatures are difficult, they were very interesting animals. You can read about them in *Animals of the Past*, by F. A. Lucas.

The rocks of the Mesozoic era (which ended some sixty million years ago) also contain fossils of flying reptiles. An artist's idea of these live airplanes of the Mesozoic is shown on page 405. Though these creatures looked somewhat like birds, all true birds have feathers and lack teeth. The flying reptiles had leathery skin and needle-like teeth, so there is no doubt that they were reptiles. Like the dinosaurs, they all disappeared with the close of the Mesozoic era.

Life of the Cenozoic Era. In the rock of the bad lands of the Dakotas, Wyoming, Nebraska, and Colorado are found the fossils of animals that lived during the early Cenozoic era. If you should examine the rocks of these regions carefully, you might find fossil teeth and pieces of bone from the skeletons of animals that lived some fifty million years ago. You might see that these remains were in some ways much like the animals of today. The Cenozoic era, indeed, is known as the Age of Mammals. The furry and hairy warm-blooded animals which are known as mammals and which are so common today first became abundant at the beginning of that era.

Fossils of a small animal that looked somewhat like a horse have been found in the rocks of the early Cenozoic. The creature was clearly much smaller than a Shetland pony, but in the shape of its head and in the proportions of its body it was horselike. In the rocks of later Cenozoic



ages there are fossils which resemble these earlier ones but which look even more like modern horses.

Indeed, the horselike fossils of the Cenozoic rocks show a gradual change from the earliest horselike creatures to the horses of today. This gradual change is pictured at the bottom of pages 406 and 407. Along with these fossil horses are fossils of animals resembling cattle, hogs, dogs, cats, camels, bears, and other familiar mammals.

Exercise. Two of the best books on Cenozoic mammals are *The Age of Mammals*, by H. F. Osborn, and *A History of Land Mammals in the Western Hemisphere*, by W. B. Scott. Look up some of the early mammals in one of these books and make a report on them for your class.

Mammals are not the only kinds of fossils in the Cenozoic rocks. The mountains west of Pikes Peak, near the town of Florissant, Colorado, contain deposits of rock which formed in a Cenozoic fresh-water lake. Near the lake a forest of giant sequoia trees once grew, similar to the big trees which are now growing in California. In time the lake overflowed the forest when near-by volcanoes dumped large quantities of ash into its waters.

The waters, containing a large amount of mineral salts from the volcanoes, protected the trees from oxygen so that they did not decay. The parts of the trunk which

were under water slowly changed to stone; that is, their cells were replaced by minerals and thus preserved. Trees which have been changed to stone are said to be *petrified.*

After a long time the land was tilted and the lake drained. A visitor to this region today can see the petrified stumps of the giant trees, as shown below. The height of the stumps above the ground from which they grew shows the depth at which the water once stood around them. The tops have decayed, but the parts of the trees which were covered by water when the lake overflowed have been changed to stone.

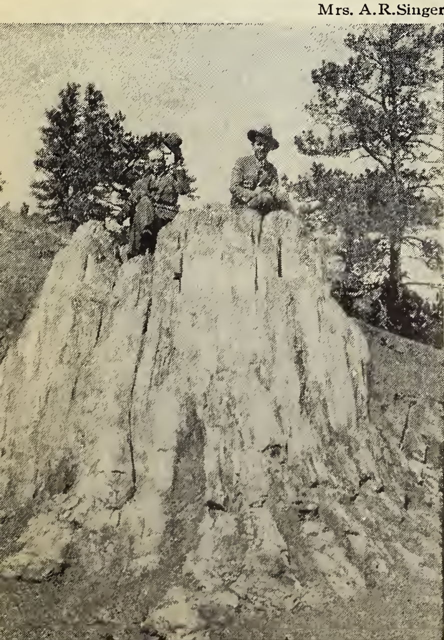
The animal life in the lake was killed, and it too has been preserved in the sediments, which are now hardened into rock. Fossils of fish, insects, and other forms of life are found in great abundance in the volcanic ashes which once rested on the bottom of this ancient lake.

The climate of North America during early Cenozoic times was mild and moist. Conditions were favorable for life, and life was abundant. Later, however, conditions changed. The end of the Cenozoic era is called the Ice Age. During this period glaciers from the north covered a large part of northern North America and northern Europe.

The Ice Age was not a continuous period of cold. At times it was cold and the ice crept southward over the lands. At times it was warm and the glaciers melted back. For perhaps a million years the ice advanced and retreated several times. The intervals between these advances are called *interglacial periods.*

This is the fossil stump of a Cenozoic tree

Mrs. A.R.Singer



During the interglacial periods animals moved northward and plants grew where the ice had been. Each time the ice advanced, the animals and plants were driven southward. The last of the glaciers began to recede, as we saw in Chapter XIII, only about thirty thousand years ago. The plants and animals now living in the regions once covered by glaciers have come in since that time.

WHAT THE ROCKS TELL US ABOUT EARLY MAN

Man is Young. What about ancient man? Are his bones preserved as fossils? If so, how old are the deposits in which they are found?

There is nothing in the rocks of the first four geologic eras to suggest the presence of man on earth. In fact, it is not until the very end of the Cenozoic era that men seem to have appeared on earth. *The oldest remains resembling man are probably no more than a million years old.* Compared with the age of the earth, man is extremely young. The rocks at the bottom of the Grand Canyon, for example, are more than one thousand times older than the oldest traces of human beings.

The Oldest Fossil Men. Some roughly chipped stones have been found in rocks which were laid down just after the middle of the Cenozoic era. These stones may just possibly have been chipped by ancient men for use as tools and weapons. The oldest traces of the actual bones of manlike creatures, however, are much younger than these stones. The Java man and the Peking man are the remains of manlike creatures that lived in Asia about a million years ago, possibly before the Ice Age. The Piltdown man lived in

England somewhat later. It is evident that early men, like early horses, were quite unlike those that live today.

The story of the discovery of the Piltdown man is interesting. Some twenty-five years ago a group of laborers who were getting gravel to make a roadbed near Piltdown, England, dug out a skull, a lower jaw, and a few other pieces of bones. Even to the laborers these bones suggested a man. Scientists were called to the scene to study the find. It was clear to them that the gravel was part of the bed of an old river, and that the bones had been washed downstream and buried where the laborers had been digging.

The skull was smaller and flatter than that of a modern man, showing that the front part of the brain was less developed. There was no question, however, that it was a human skull. The jawbone found near the skull was heavy and much less human. The teeth were extremely long and pointed, unlike those of any modern man, and the jaw was chinless. After careful study, the scientists agreed that Piltdown man had lived in England some hundreds of thousands of years ago, and that he had a fairly well-developed brain even though his jawbone and teeth were more like those of an animal than a man

This model of a Neanderthal man was based on fossil bones discovered in European caves

From a model by Frederick Blaschke, © F.M.N.H.

Neanderthal Man. The Java, Peking, and Piltdown men are not the only known human fossils. The bones of a later fossil man, Neander-

thal man, have been found in caverns in Germany, Belgium, and France. The illustration on the opposite page represents a scientist's idea of the Neanderthal man—the cave man of the storybooks.

The stone tools and weapons used by these men were extremely rough. They were made chiefly of flint, and were chipped to a size and shape to fit the hand. There was no polishing of sharp edges, as was true of the stone implements of a later day. In order to tell these early rough instruments from the better-made later ones, we speak of them as belonging to the Paleolithic, or Old Stone, Age. The later ones, more skillfully made and better finished, belong to the Neolithic, or New Stone, Age.

Neanderthal man lived in the period of time that came just before the beginning of the fourth and last advance of the glaciers. Many skeletons have been found in caverns and rock shelters, together with rude implements and the bones of such animals as the mammoth, the saber-toothed tiger, the reindeer, and the woolly rhinoceros. From the skeletons we know that Neanderthal man walked with shoulders slightly slouched forward and with knees bent. His hands were large and his arms long.

The weapons that he left and the bones of animals associated with his own show that he was a hunter who roamed over the land in search of the reindeer and the mammoth. His Europe was a cold country, and he needed good warm skins and nourishing food. He lived within the shelter of caves, but probably not far inside because of the dampness and darkness. He was really a "rock-shelter" man rather than a "cave" man.

The Cro-Magnon Man. When the last ice sheet of the Ice Age crept over Europe, Neanderthal man disappeared.

© A.M.N.H.

The Cro-Magnon man was a sensitive artist[1]

In time another race of men, probably immigrants from Asia or Africa, took possession of Europe. They are known as Cro-Magnon man (named from the cave in France where one of the first skeletons was found). The Cro-Magnons gradually replaced the few Neanderthals that had survived, just as the white men have within a few generations replaced the Indians in North America.

The Cro-Magnons were much more advanced than the Neanderthals. Their skulls show that they had large brains with high foreheads. Their hands show that they were well able to make and to use fine tools. The shape of their leg bones proves that they walked erect. They were taller and better looking than many modern Europeans.

These men used stone implements which were carefully and beautifully made. They painted pictures on cavern walls and carved images on the tusks and horns of animals. They made and decorated pottery. They modeled little

[1]From a painting by Charles R. Knight under direction of Henry Fairfield Osborn.

clay gods and goddesses. They lived in the open, although usually near caves along river banks.

Cro-Magnon man was always a hunter. He had no domestic animals and he raised no crops. As a result his home was in no particular place, for he had to go where food was abundant. Though a good artist, he seems to have had no written language. The illustration on the opposite page shows the Cro-Magnon man decorating the wall of a cave with pictures of mammoths. The Cro-Magnon man was the first human being to show in a marked degree the physical and mental traits of man as we know him today.

Exercise. Look up Osborn's *Men of the Old Stone Age*, one of the best books on early man. It has good pictures illustrating the work of scientists in unfolding the story of primitive man, and many pictures showing the life of these early people.

The Coming of Modern Men. One must not think that the Cro-Magnon people were the direct ancestors of the present races of Europe. The evidence seems to show that these people died out, and that some ten or twelve thousand years ago other races came to live in Europe. These newer races lived in villages, kept domesticated animals, practiced religious ceremonies, made jars from clay, and worked in bronze. This was a great advance over the culture of any of the earlier peoples.

The oldest signs of this more advanced culture are found in western Asia and northern Africa. It seems likely that the people who took the place of the Cro-Magnons in Europe came from one of these regions. During the few thousand years before the dawn of recorded history they seem to have spread to all parts of the world. They seem to have moved into eastern Asia, where they became the

ancestors of the modern Chinese and Japanese. Apparently they crossed Bering Strait from Asia to America and became the ancestors of the Eskimo and the American Indian. Some of them moved into Europe and developed into the Europeans of today.

The first people to leave a written record lived about six thousand years ago. These first records show that the early civilizations possessed a high degree of culture. Without doubt many of the qualities of modern civilization had developed before the earliest written records, when people learned to live together to their common advantage. It would seem that men had built homes, cultivated the soil, engaged in commerce, and developed some form of government before they learned to write.

The Rise of Civilization. The sweep of developing civilization from the Old Stone Age to today is too long a story to tell at length here. A great many books have been written about it, some of which you can probably find in your school library. The following paragraphs contain but the barest skeleton of the story.

Following the Stone Age, copper and then bronze became the bases of civilization. Finally the use of iron was discovered. Man made a great advance when he learned to polish rough stones, but many thousands of years passed after this before he learned to take iron from ore and to make it into tools, weapons, and machinery.

Throughout all these stages in man's development his culture increased. Traces have been found of a very early people who lived in what is now Switzerland. These people built wooden homes upon platforms along the shores of lakes. These platforms were supported by piles driven into the ground, as illustrated on the opposite page. On the

From a painting by Contau in Musée Rath, Geneva

The early Swiss lived in houses built on piles by the waters of ancient lakes

shores of these lakes the remains of an agricultural civilization have been discovered.

Over four thousand years ago the Assyrians and the Egyptians had developed very high cultures. The great civilizations of ancient Greece and Rome are over two thousand years old. The earliest American civilizations had their origin in races that probably came into America from Asia. Recent discoveries show that early civilizations of rather high order were developed in many places on the American continents.

The American Indians belonged to the New Stone Age, because for the most part their implements and weapons were made of stone. The best authorities at present believe that probably somewhere between twelve and thirty thousand years ago the first "Indians" crossed from northeastern Asia into Alaska, and then spread southward through North and into Central and South America.

Exercise. For a good account of how scientists have found out about the ancient Mayan civilization of Central America, read Morris's *Digging in Yucatan.* This tells you something about Chichen Itzá, or the City of the Sacred Well. If you want a really exciting adventure story of ancient civilizations, read Janvier's *The Aztec Treasure House.* As you read it, however, remember that it is imaginary.

From this very brief sketch of the development of civilization you can see that the history of man on earth is a history of progress. Man developed from a condition in which he could do nothing more than fashion pieces of stone into crude tools and weapons. Compare that condition with his condition today. Riding in automobiles and airplanes, talking over the radio, building skyscrapers,

answering questions concerning the nature of things, and expressing his feelings in many arts, man has traveled far indeed from the Stone Age!

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. The dinosaurs were fierce enemies of primitive man.

2. If you dug up an old necklace in your garden, you might rightly call it a fossil.

3. The ancient Archeozoic rocks are so deeply buried by younger formations that we cannot reach them to see if they contain any fossils.

4. The Proterozoic rocks are completely lacking in the remains of life, probably because the creatures of that time were too small and soft to be preserved.

5. Trilobites, fishes, and dinosaurs were the commonest animals of the Paleozoic era.

6. The dinosaurs were all large, bloodthirsty beasts.

7. The flying reptiles of the Cenozoic era were like birds excepting that they had no teeth.

8. The Age of Mammals came to a close with the Ice Age, when all the mammals died.

9. Fossil trees are common in the Paleozoic rocks, but they are absent from the rocks of later eras.

10. Horses smaller than Shetland ponies played with small dinosaurs on the Mesozoic pastures.

11. The Piltdown man of Asia is the oldest fossil man known.

12. The Neanderthal man was tall and good-looking, a good artist, and a fine hunter.

Questions for Discussion

1. What reasons can you think of to explain the disappearance of many plants and animals during the past?

2. Do you think that dinosaurs could live in any part of the world today?

3. A statement has been made that "the cultures of all people today have much in common." What do you think is meant by this? Do you have any evidence to support it?

4. Are there any living peoples who are not much farther advanced than some of the types of early man?

Things to Do

1. Prepare a geologic time chart showing the major eras in the earth's history. Indicate in each era the kinds of life that flourished during that time.

2. Read *The Life of a Fossil Hunter*, by C. H. Sternberg. This is an interesting story by a man who helped collect dinosaurs and other fossils on the Western plains at a time when fossil-hunters had to be Indian fighters as well.

3. Here are some stories that you may like to write. Be sure that your facts are correct as far as you can make them so.

The Life Story of a Dinosaur
A Boy in the Old Stone Age

4. What evidence can you give to show that the life of modern man shows progress over that of primitive man? Prepare a report on this for your class, containing comparisons of dress, tools, weapons, houses, art, and literature.

5. Try to find out something about the primitive peoples who are living today. Prepare an illustrated booklet on the subject. Compare the life of such people with the life of people who lived in the New Stone Age or the Bronze Age.

UNIT FIVE

OUR LIFE IN A CHANGING WORLD

In our studies of a changing world we have roamed among the stars in the dim distances of space.

We have roamed among the dinosaurs in the dim distances of the past.

We have watched the changing weather, the changing creatures, and the changing landscape of the earth.

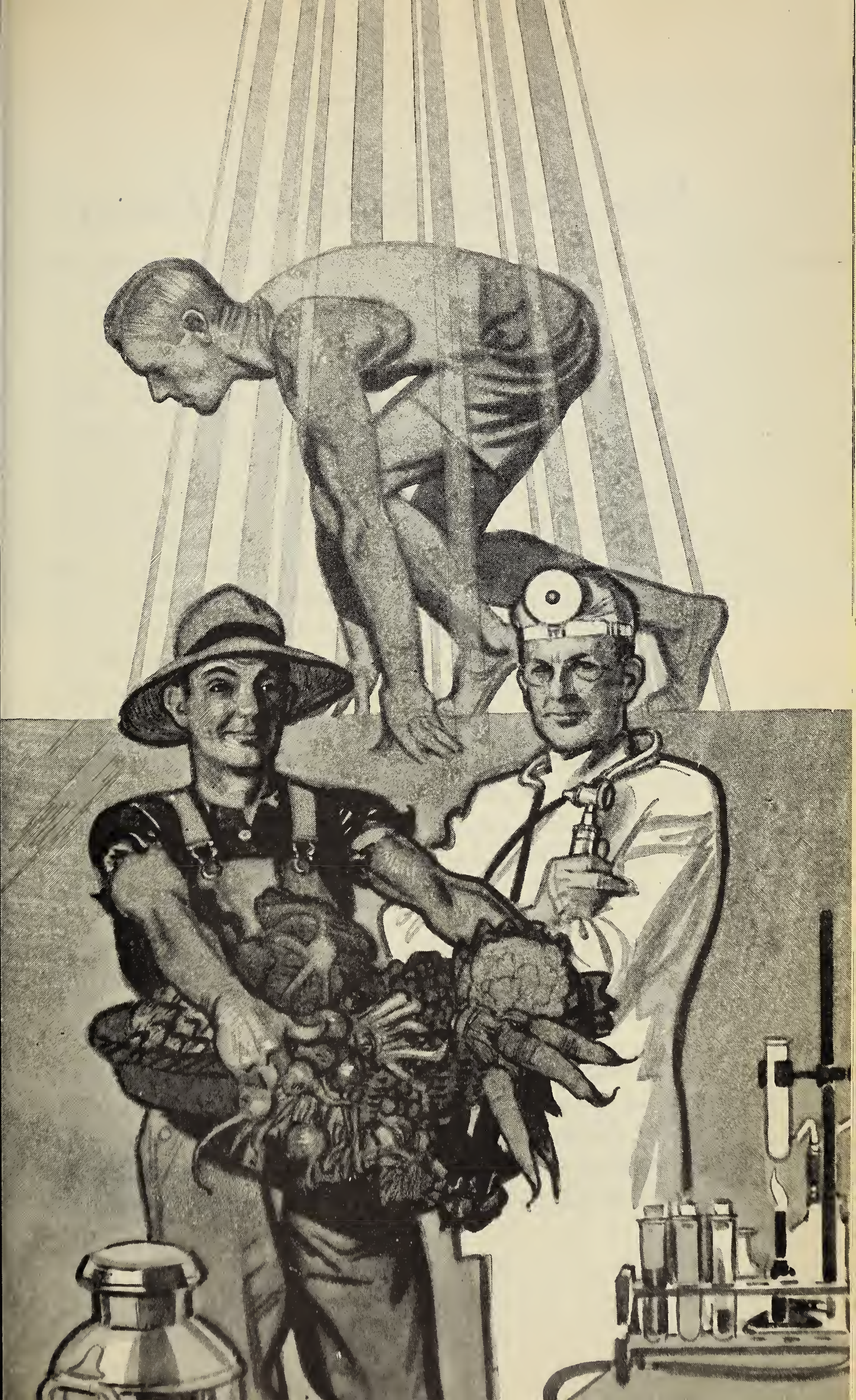
Let us now turn to ourselves.

We too are part of a changing world.

How do we seize our share of the earth's energy and use it to build our lives?

How can we preserve that most precious possession, health?

Unit Five of this book will try to answer these questions.



CHAPTER SIXTEEN

How Do Our Bodies Use Energy?

THE NATURE OF FOOD

What the Sun Does to the Earth. All through this book we have been studying change—in one form or another. There is something in the world which keeps it forever on the go, and we call that something *energy*. In Chapter Two we saw that all the earth's energy comes from the sun. This "solar" energy, as it is called, is the direct or the indirect cause of all the changes on earth. It is the direct or the indirect cause of everything we human beings do.

How does the energy of the sun reach us and how do we use it to live in a changing world? We have already seen how rocks are broken down directly by the radiant energy of the sun and indirectly by wind and running water which have been set in motion by this energy. We have seen how the soil which results from the breaking down of rocks provides materials which are necessary for plant and animal life. What the sun does for plants and animals it also does for us—as we shall see in detail in this chapter.

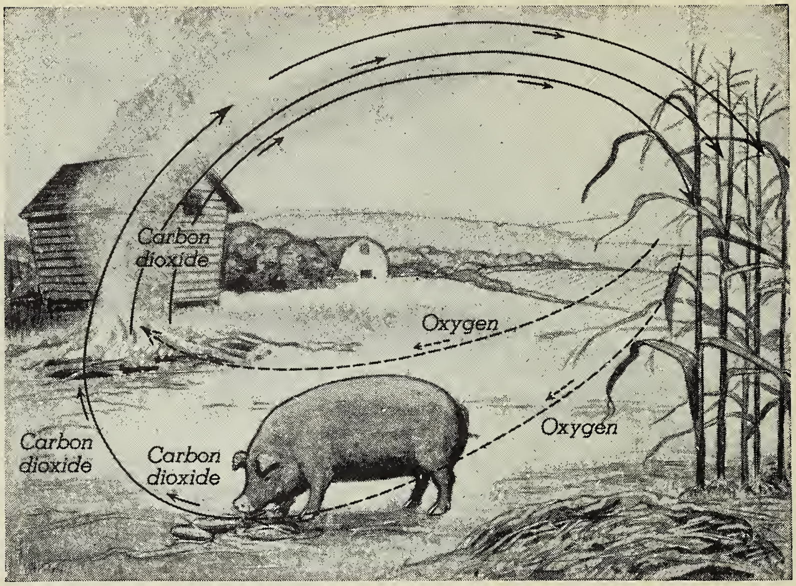
Exercise. Study the drawing on the opposite page and make a written list of all the illustrations it contains of the effects of solar energy.

The Carbon Cycle. As you travel through the country, you see many kinds of growing things: grasses, flowers, weeds, forests, and fields of waving grain. *All these plants are made to a large extent of carbon, a solid that came from the air in the form of gaseous carbon dioxide.* Thousands

How many effects of solar energy can you find in this picture?

of pounds of carbon are locked up, for example, in a field of corn. The carbon, however, does not long remain locked up. In a short time the ears of corn will have been used for food; the roots and stems will have decayed or been burned. The carbon is thus turned back to a gas and to the air as carbon dioxide. These changes are known as the carbon cycle, and they are illustrated in the diagram on page 424. Do you see that the carbon keeps going round and round in a sort of circle? The carbon cycle is well named because "cycle" means "circle."

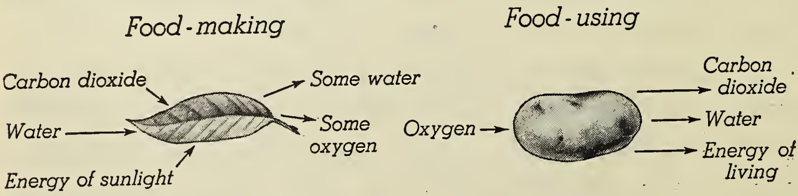
Notice that the pig enters the cycle by eating the corn and by turning some of the solid carbon of the corn into gaseous carbon dioxide. Many other animals enter the carbon cycle in much the same way. We enter it in this way ourselves.



Can you trace the carbon cycle in this diagram?

Exercise. Prepare a wall chart to illustrate the carbon cycle. Use a number of drawings or photographs to illustrate different stages in the cycle, and arrange them in a circle.

Food-making and Food-using. Some of the carbon dioxide that is released into the air from the lungs of animals and men, from the processes of decay, and from the fuel that is burned in furnaces throughout the land, is used by green



How energy is stored and released by living creatures

plants to make food. *This process of food-making, as we have seen in our earlier studies, consists in the production of starch and other foods from carbon dioxide and other mineral materials.* It goes on only in the cells of green plants and only in the presence of sunlight. It is an *energy-storing process* because it locks up the energy of the sun in the bodies of living creatures.

It is the exact opposite of the process of food-using, which goes on in our bodies as well as in the bodies of plants and animals. This process is an *energy-releasing process*, because by turning the carbon of food into carbon dioxide it releases energy for the everyday business of living. The diagram on the opposite page shows what happens in the processes of food-making and food-using.

The amount of energy that is released in food-using is equal to the amount that is stored in food-making. All parts of the human body need food. The energy from food keeps our bodies warm and enables us to work and play.

The Carbohydrates. In earlier studies in science you have probably learned that our food is of different kinds, each kind with its own special work to do. You have probably learned that the carbohydrates (so-called because they are made of the elements carbon, hydrogen, and oxygen) are the most abundant foods in our diet. Let us examine the carbohydrates a little more closely here. What are they, and how are they formed, and what do they do for us?

There are three main types of carbohydrates: sugar, starch, and cellulose. The simplest form of sugar is the sugar of fruit, which is known as *glucose*. In plants glucose may be changed to other forms of carbohydrates. In the sugar cane and the sugar beet the glucose is changed into *sucrose*, the common sugar which is used on our tables.

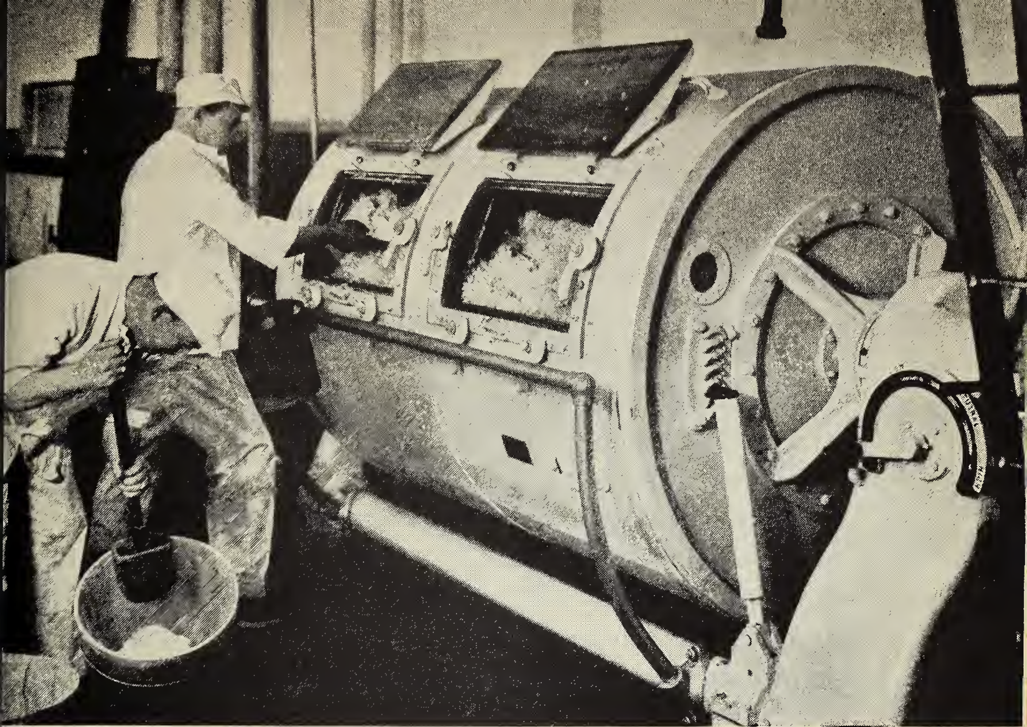
Carbohydrates in great abundance are stored in plants in the form of *starch*. Starch differs from glucose and sucrose in that it does not dissolve in water. It is stored in plants, especially in seeds. Grains of wheat, oats, rye, and rice contain large percentages of starch. White potatoes, sweet potatoes, carrots, onions, celery, and most other vegetable foods are chiefly, but not wholly, made of starch and water.

Cellulose makes up the tough woody parts of plants. It is the thing that crunches when you take a bite of celery. Both cellulose and starch are insoluble in water, but starch is easily changed to a soluble substance by digestion. Unlike cattle, sheep, goats, and several other animals, we cannot digest cellulose. It is, nevertheless, an important part of our diet.

For good health we must use foods that are not too concentrated. Concentrated foods contain but little cellulose, and are almost completely digested and absorbed by our bodies. Coarse foods contain cellulose, and the cellulose is left in the intestines after the digested foods are absorbed into the blood. This cellulose is necessary for helping the body get rid of waste. It is sometimes referred to as "roughage," and its action is a little like that of a rough cloth on a windowpane. It cleans by rubbing.

The Fats. Like the carbohydrates, the fats are made of carbon, hydrogen, and oxygen. These elements, however, are put together very differently in these two great classes of food, and as a result must be handled very differently by our bodies.

When you speak of "fat" meat, you use the word to distinguish between "fat" and "lean." The farmer and the butcher know that *lard* is made from fat pork. In the proc-


Ewing Galloway

These men are making butter in a modern churn

ess of making lard, fat is separated from the muscle tissues which make up the so-called lean meat. Fat may be melted down from beef and mutton in the same manner. Fat from these sources is called *tallow*, and is similar to lard in chemical properties. *Butter* is another kind of fat. The cream that rises to the top when milk is allowed to stand is butter fat. It is similar to lard and tallow, but it does not taste the same.

Still other fats are taken from plants, and are known as *oils*. Olive oil and linseed oil are similar to butter and lard in chemical properties. These vegetable oils are really vegetable fats. You should recognize the difference between vegetable oils and mineral oils. Mineral oils are derived from petroleum and are used chiefly for the lubrication of machinery. Highly refined mineral oils are sometimes used as medicines. But neither these nor any other mineral oils

have any value as food, because they cannot pass through the walls of the intestines and into the blood.

The Proteins. In one sense the proteins are our most important foods. Carbohydrates and fats are our chief source of energy, but they cannot supply the elements which are necessary for building muscle and bone. Only the proteins can do that. We get our proteins chiefly from lean meats, eggs, milk, cereals, peas, and beans.

Chemists have found that proteins are extremely complex substances, but, like fats and carbohydrates, they are broken down into simpler substances by digestion. The proteins are composed of chemical compounds which are known as *amino acids*. Like carbohydrates and fats, they contain carbon, hydrogen, and oxygen. In addition they contain nitrogen and other elements, especially sulfur, phosphorus, and iron. At least twenty *amino acids* are known. A great number of proteins may be formed from them, just as a great number of words may be formed from the letters of the alphabet.

Exercise. Make a list of the things you eat during one day. From which foods did you get most carbohydrates? most fats? most proteins?

WHAT HAPPENS TO THE FOODS WE EAT

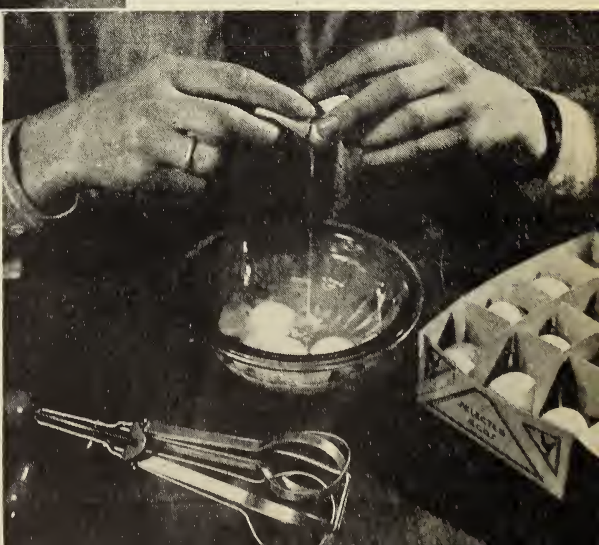
The Story of Yesterday's Dinner. Let us suppose that you dined yesterday on bread, butter, beef, potatoes, spinach, and fruit with sugar. You also used some salt and water. What happened to these foods after they were taken into your body?

The bread was composed mostly of starch. It also contained some protein and a small amount of fat. The butter

A banana is a storehouse
of carbohydrates

Butter is an excellent
source of fat

Eggs are rich in protein



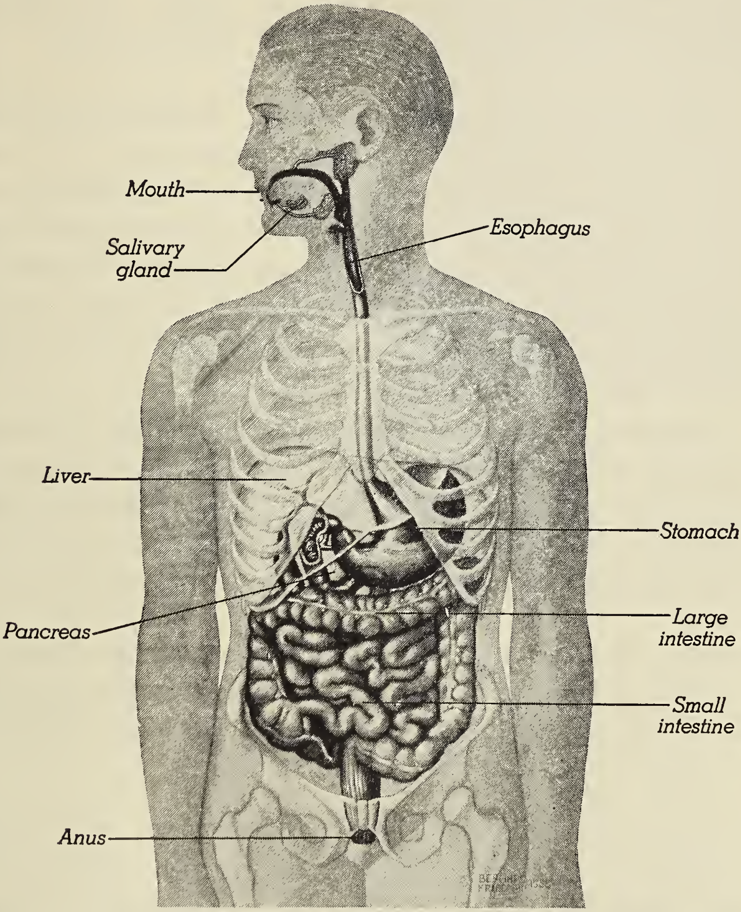
was almost entirely fat. The beef was mostly protein, but it contained some fat. The potatoes were mostly starch and water. The spinach contained some starch, a small amount of protein, a little fat, some mineral salts, and a considerable amount of cellulose. The fruit probably contained some glucose and possibly a small amount of protein and cellulose. The sugar was nearly pure sucrose. In other words, your lunch was composed of carbohydrates, fats, and proteins, together with salt and water.

It is easy to understand what happened to the water. It was taken into your stomach, whence it passed almost immediately into your intestines. It then seeped directly through the walls of your intestines to become in a very few minutes a part of your blood. The salt you used went along with the water and was also soon in your blood stream. Neither of these was changed in any way by the process of digestion.

The glucose also passed directly into your blood. The sucrose and the starch, on the other hand, went through considerable change, but in the end they became glucose and entered your blood. The cellulose was indigestible, and was expelled from your intestines as waste. The fats and proteins were dissolved in the digestive fluids (which we shall study later), and then were absorbed by the blood after they had seeped through the intestinal walls.

It is clear from the above that *the purpose of eating is to get food materials into the blood, where their energy may be used to carry on the business of living*. It is also clear that only water, glucose, and dissolved mineral matter can get into the blood without first going through the process which is known as digestion. Let us next see what this process is, and what the machinery is that makes it possible.

The Machinery of Digestion. The word "digestion" comes from two Latin words which mean "to carry apart." The



The human digestive system is an irregular tube about thirty feet long[1]

business of digestion is to change food so that it can be absorbed by the blood. The machinery of digestion is known as the *digestive system*. If you look carefully at the diagram above, you will see that the digestive system is a long

[1]From Andress, Goldberger, Hallock, *Safe and Healthy Living.*

tube which extends from the *mouth* at one end to the *anus* at the other end. Because this tube is some thirty feet long—much longer than the space it must occupy—the lower part of it is coiled back upon itself in several places.

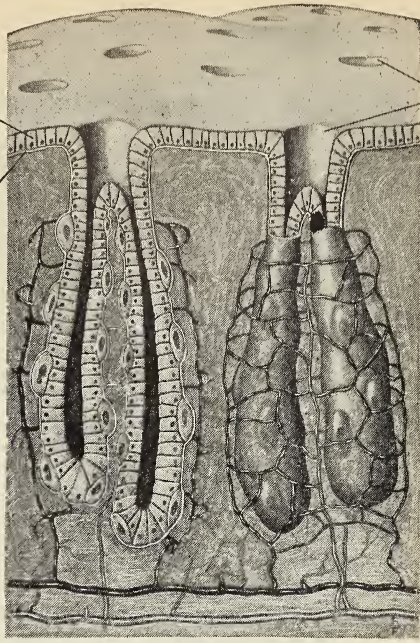
What Happens to Food in the Mouth. Everybody knows that our mouths contain teeth for grinding food. It is in the mouth that our solid foods are broken into small pieces so that they may be more easily dissolved by the digestive juices when they reach the stomach and the intestines. Remember that *our bodies cannot use food which is not first dissolved.* Cooking makes many foods more easily soluble, and so does chewing.

Everybody knows that when food is chewed, saliva from the *salivary glands* is mixed with it so that it becomes moist and more easy to swallow. Not everybody knows that saliva does more than merely lubricate our food. It contains a chemical substance which actually dissolves starch.

Exercise. Chew a bite of bread or unsalted cracker until it is thoroughly mixed with saliva. Hold it in your mouth for two minutes before swallowing. Does the bread or cracker begin to taste sweet?

This simple experiment will show you very clearly that the digestion of starch begins in the mouth. The sweet taste that comes when a starchy food is chewed for a long time is due to the fact that *saliva turns starch into glucose.* Not until the starchy foods are turned into glucose can they be absorbed by the blood.

Do you see, then, one reason why you should chew your food well before swallowing it? It is not necessary to hold starches in the mouth until they are completely changed into glucose, because this process is continued in the intes-



The glands of the stomach make a juice which helps to digest protein

tines. But it should *start* in the mouth, and much indigestion could be avoided if people ate more slowly and chewed more thoroughly.

What Happens to Food in the Stomach. When food is swallowed, it goes down the first part of the digestive tube (the *esophagus*) and into the stomach. The stomach is a mill that mixes the food with chemicals (the *gastric, or stomach, juice*) which are made in little cups, or *glands*, in the stomach lining. One of these glands is shown above.

None of the chemicals which are made in the stomach has any effect on the carbohydrates. These foods are merely mixed into a paste in the stomach and then pushed into the small intestine, where their digestion is completed. Fats, too, are largely digested in the small intestine. Proteins, however, are changed in the stomach by the gastric juice so that they may later be dissolved and absorbed. *Hydrochloric acid* and *pepsin* are in the gastric juice, and they are chiefly responsible for this important work.

Exercise. How to show the effect of the gastric juice on protein: Dissolve a pinch of dry pepsin and a quarter teaspoonful of concentrated hydrochloric acid in a glassful of warm water. Be very careful not to spill any of the acid on yourself or your clothes. Chop fine a teaspoon-

ful of the white of a hard-boiled egg, and put it in the solution. What happens to the white of the egg after it has stood for a while?

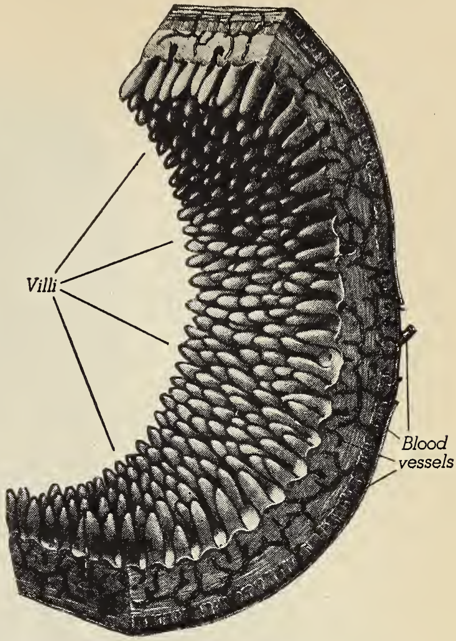
What Happens to Food in the Small Intestine. In the drawing on page 431 you will notice that when food leaves the stomach it enters the small intestine. Notice that the *liver* and the *pancreas* are attached to the upper end of the small intestine, just below the place where it joins the stomach. It is the business of these two organs to manufacture chemicals that will carry on the digestion of our food.

The chief work of the liver is to make *bile*, which helps to dissolve fat. The chief work of the pancreas is to make *pancreatic juice*, which helps to dissolve all three types of food,—carbohydrates, fats, and proteins. These organs are aided in this task by the small intestine itself, which continually churns and mixes the food with the juices, and which manufactures juices of its own that help in the digestion of the carbohydrates and proteins.

The illustration on the opposite page shows the lining of the small intestine. Notice the many tiny fingers of flesh which extend from the lining into the interior of the tube. These are the *villi* (singular, *villus*), whose business is to absorb the digested food from the intestine. Notice the tiny blood vessels that gather the dissolved food from the villi and carry it into the blood of the entire body.

By the time our food reaches the lower end of the small intestine (a journey of about twenty feet, which takes from two to five hours), digestion is practically completed. Nearly all the food that can be dissolved has been dissolved; nearly all that can be absorbed into the blood has been absorbed. The waste materials, consisting chiefly of cellulose and water, are pushed into the large intestine.

What Happens to Food in the Large Intestine. The large intestine (so called because it is greater in diameter though less in length than the small intestine) absorbs much of the water that was not absorbed by the small intestine. Its chief work, however, is to store waste material and from time to time to expel it through the anus.



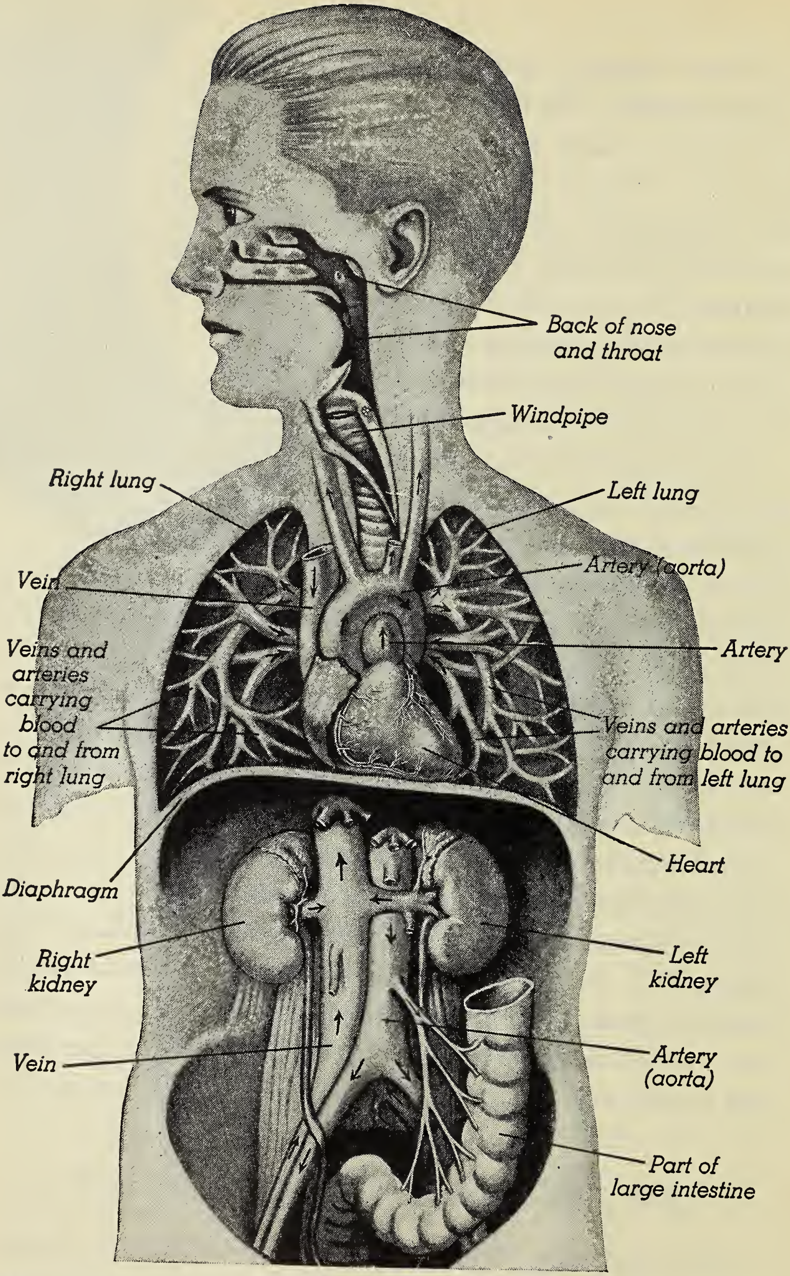
Tiny "fingers" inside the small intestine absorb the digested food

The large intestine is a breeding ground for bacteria that feed on little particles of food which escape absorption in the small intestine. These bacteria cause the material in the large intestine to decay and to swell, with discomfort or illness a frequent result. For this reason we should not allow waste material to remain very long in the large intestine. Most people in good health have one thorough movement of the bowels every day.

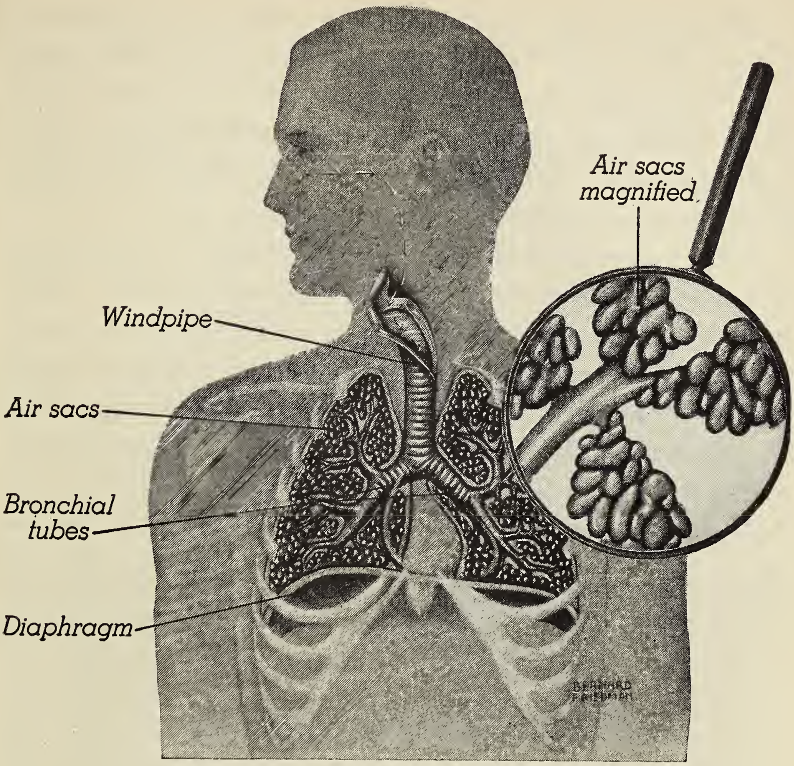
In studying the travels of food through our bodies and the changes it undergoes while traveling, we have really studied how the energy of the sun serves our needs. The energy that was first stored in the green leaves of plants and then changed in various ways into the foods we eat has now entered our blood. How is it released from the blood and turned into the energy of work and play? Let us see.

HOW THE ENERGY OF FOOD IS RELEASED

How the Lungs Work. To understand how our bodies make use of food we must turn from the process of eating to the process of breathing. The machinery of breathing



The respiratory and circulatory systems of the human body are closely related



The air tubes in the lungs branch like the roots of a plant[1]

is known as the *respiratory system.* It is closely associated with the machinery that circulates the blood and which is known as the *circulatory system.* These two systems are shown in the diagram on the opposite page, and the following discussion will explain how they work.

If you turn back to the illustration on page 424, you will see that *oxygen must come in contact with food before its energy can be released.* The purpose of breathing is to bring the oxygen of the air into contact with the blood and with the dissolved food which the blood contains.

[1]From Andress, Goldberger, Hallock, *Safe and Healthy Living.*

When you breathe in air (*inhale*) through your nose or mouth, the muscles which are attached to your ribs move so as to enlarge your chest. Air travels down your *windpipe*. Inside your chest the windpipe divides into two pipes (the *bronchial tubes*), one going to each lung. In the lungs the branching continues, as shown on page 437.

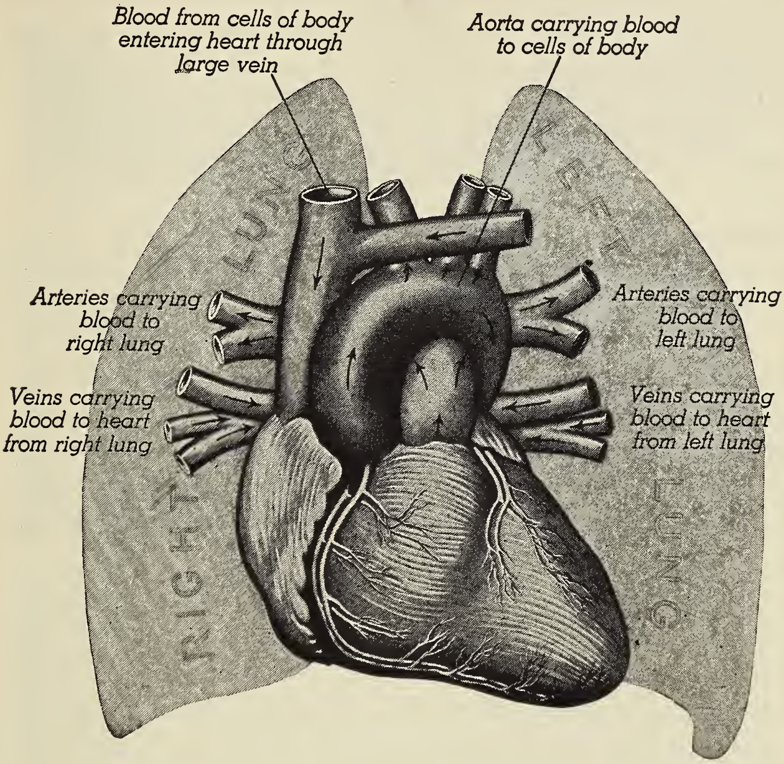
Notice that the branching of the air tubes in the lungs resembles the branching of the roots of a plant. Each branch divides into smaller branches, and these in turn into still smaller ones. The branching continues until the tiniest branches end in little cavities, or *air sacs*, as shown in the illustration. When you inhale, air fills the little tubes and sacs in your lungs, and the lungs expand like a rubber balloon.

Exercise. How to measure the amount of air your lungs can hold: Get a one-gallon jug and fill it with water. Hold your hand tightly over the mouth of the jug so that no water can escape, and then turn it upside down in a pan of water. Take a deep breath and blow into the jug through a rubber tube, as shown below. Can you force out all the water in the jug with one good blow?

How the Blood Gets Oxygen. You know that your blood is always moving, or circulating, through your body. It is kept moving by the most remarkable pump in the world, the human *heart*. The pipes through which blood flows into the heart are called *veins*; those through which blood flows out of the heart are called arteries. On the opposite page is a diagram

This girl is measuring the amount of air her lungs can hold

of the heart with the most important blood vessels that connect with it. Study it carefully.



The human heart is a pump

Notice that one of the large arteries carries blood directly from the heart to the lungs. Near the lungs it branches (just as the large air tube does), and one branch goes to each lung. In the lungs the arteries branch again and again (just as the air tubes do), until they have divided into the very tiny tubes, or *capillaries*. These capillaries carry the blood to the air sacs and are so small that they can only be seen with the help of a microscope.

Air held in extremely thin-walled sacs and blood moving through extremely thin-walled blood vessels around the sacs do what might be expected. The gases of the air in the sacs—including the life-giving oxygen—pass through the thin walls and into the blood. The gases which are dissolved in the blood, on the other hand, pass into the air sacs and are later expelled when you breathe out (*exhale*).

Exercises. Get a sheep lung from your local butcher. Put a rubber tube into one of the bronchial tubes that branches from the windpipe, and blow up the lung. Then let the air escape. By repeating this performance over and over, you can obtain a good idea of the behavior of a lung during breathing.

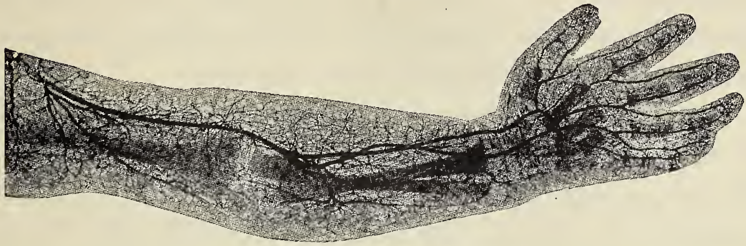
Blow up the lung and then cut off a piece of it with a sharp knife. Examine the cut surface with a magnifying glass and see if you can recognize the air sacs and capillaries.

Let us now follow the blood which has absorbed oxygen from the air sacs. The little capillaries that brought the blood in contact with the air sacs also lead it away. If you should trace the branching blood tubes *away* from the air sacs, you would find them doing just the opposite of what they do in approaching the air sacs. Instead of dividing into smaller and smaller tubes, they unite to form larger and larger ones. Finally two large branches are formed, one from each lung, which unite in one great vein that leads back to the heart (see illustrations on pages 436 and 439).

Do you see, then, that blood is pumped from the heart to the lungs and then back to the heart again? What happens to it next?

How Oxygen Is Spread through the Body. The oxygen-bearing blood that has entered the heart from the lungs

is immediately pumped out again through the great artery which is called the *aorta* (see diagram on page 439). Smaller



This X-ray photograph shows how blood is piped to every part of the arm[1]

arteries branch from the aorta and carry the blood to every part of the body. The photograph above shows how the blood is piped through millions of little tubes to every part of the arm. Similar pictures could be made for every other part of the body.

What happens to the blood in these tiny tubes? Just as in the lungs, the tiny blood vessels in the arm have very thin walls. A white liquid from the blood (with oxygen dissolved in it) seeps through the walls and into the cells which make up the flesh and bone of the arm. In this way *every living cell in the body is bathed continuously by the liquid from the blood.* It is this liquid (which is known as *lymph*) that keeps our bodies alive. Let us next see how this is done.

How Oxygen Frees the Energy of Food. Earlier in this chapter we learned that food is digested and absorbed into the blood through the walls of the small intestine. The process of food absorption is similar to the process of oxygen absorption. The blood vessels around the small intestine

[1]From Gruenberg's *Biology and Human Life.*

are extremely tiny, and the dissolved food passes through their thin walls and into the blood. Do you see, then, that the blood becomes a carrier of oxygen taken from the lungs and of digested food (which is chiefly carbon, hydrogen, and oxygen) taken from the small intestine?

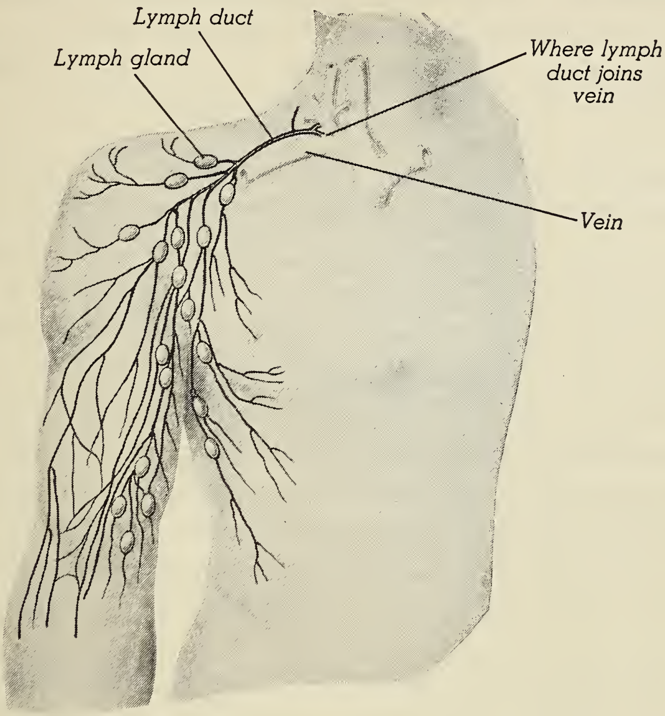
The oxygen combines with the carbon and hydrogen in the blood, and heat is produced. *This chemical change is the same as that which goes on when a candle burns, excepting that it is slower.* The heat produced by this change keeps our bodies warm. It is really the energy of the sun which was locked up for a time in our food and then released in a form that our bodies can use. The liquid that bathes every cell in our bodies not only brings energy in the form of heat. It brings the energy which enables us to do all the things that make up our work and play.

What Happens to the Waste Products in the Blood. Earlier in your study of science you probably learned that the products from a burning candle are carbon dioxide and water. These same products (and certain others) are formed by the chemical change which takes place in the cells of the body. The carbon dioxide and water thus formed in the body are waste products, and must be removed from the cells.

They are carried away from the cells by two different routes, but by either route they move from the cells toward the heart. One route is through the blood vessels. The capillaries that carry oxygen and food to the cells connect with the veins which carry away some of the waste products. Thus the blood that flows back to the heart through the veins carries waste products with it.

The other route is through another set of tubes which carry waste products, together with lymph, away from the

cells. As in the case of the veins and arteries, these so-called *lymph ducts* keep joining to form larger and larger ducts.



The lymph ducts are an important part of the plumbing of the human body

Finally the largest lymph ducts join the veins, as shown in the illustration above. The waste and lymph thus enter the blood just before the blood reaches the heart.

From the heart the waste-filled blood passes to the lungs and to the tiny blood tubes which surround the air sacs. Carbon dioxide and water pass through the walls of the blood tubes into the air sacs, and from there on out of the lungs.

Exercises. How to show that your breath contains carbon dioxide: Limewater turns milky when it comes in contact with carbon dioxide. Breathe through a glass tube into a bottle of limewater. What happens?

How to show that your breath contains water vapor: Breathe on a windowpane. What happens?

The Work of the Kidneys. There are other waste products from the cells besides carbon dioxide and water. These are carried in the blood stream to the kidneys, where they are removed from the blood and later from the body in the urine. The waste which is removed by the kidneys is different from that which is removed through the action of the large intestine. The latter is largely indigestible material which cannot be absorbed into the blood stream. It has no part in the changes that go on in the cell. The waste which the kidneys remove, on the other hand, comes directly from chemical changes in the body cells. Similar waste is also expelled through the skin in perspiration.

The Carbon Cycle Again. We have now come to the end of this chapter, and in doing so we have also returned to the beginning. Our study of the digestive, respiratory, and circulatory systems was necessary to make clear the way we use energy which first came to the earth in the rays of the sun. It was necessary to explain exactly how we play our part in the carbon cycle.

Just playing a part in anything, however, is not enough. We all want to play our parts as well as possible. How can we help our bodies to play their part in the important business of releasing the energy of food? The next chapter will answer this question.

Correct These Statements

The following statements are partly or wholly false Correct them and discuss your corrections.

1. Carbon is one of the commonest elements in nature and is seldom changed in form.

2. Food-making and food-using are much the same excepting that water is necessary in the first process but not necessary in the second.

3. Starch is really made of three different things: glucose, cellulose, and carbohydrate.

4. "Glucose" and "sucrose" are different names for the same thing because both are forms of sugar.

5. Because olive oil and butter are quite different chemically, they are handled differently by the digestive system.

6. The sugar we eat is digested largely in the mouth.

7. The only important work of the saliva is to make food slide down the throat.

8. The stomach is a mill that grinds up food but does not act upon it chemically.

9. The villi are little blood vessels which carry digested food to every cell of our bodies.

10. The large intestine is larger than the small intestine because it has more work to do.

11. The purpose of lungs is to bring nitrogen into the blood.

12. Air and blood flow through the same tubes in the lungs so that the air and blood may be thoroughly mixed.

13. Heat is produced when the oxygen from the air and the hydrogen from digested food combine in the blood.

14. Our bodies have only two ways of getting rid of waste: through the large intestine and through the lungs.

Questions for Discussion

1. The body is often referred to as a machine. Do you think this is a correct statement? Why?

2. How many examples can you give from this chapter of the teamwork between different parts of the body?

3. What happens when people suffocate? What is good first-aid practice in such cases? Do you know how a pulmotor works?

Things to Do

1. Look up in a book of hygiene or physiology (*a*) what work the liver does besides manufacturing bile; (*b*) how digested fat is turned back into fat and built into our bodies; (*c*) what effect anger, fear, and other unpleasant emotions have on digestion.

2. Test the effect of saliva upon starchy foods. Make up a starch solution by stirring into boiling water some powdered starch. Pour some of this solution into a clean test tube and add several drops of saliva. Place the tube in a beaker of water, the temperature of which is about that of the human mouth (between 90° F. and 100° F.). Keep the test tube in the warm water for ten minutes. Now add several drops of the starch and saliva to a test tube partly filled with Fehling's solution. Boil and note color (brick-red color indicates the presence of glucose). Then make the Fehling's-solution test on starch which has *not* been treated with saliva. Compare your results. What conclusions can you draw from this experiment?

3. Prepare a wall chart showing how air enters and leaves the lung and how the blood carries oxygen to the cells.

4. Examine the circulation of blood in the web of a frog's foot by holding the frog in your hand while looking at the web through a microscope.

CHAPTER SEVENTEEN

What Is Health?

HOW HEALTHY BODIES PERFORM

Good Health Is Natural. When our bodies are working as they should work, we are scarcely aware of their working at all. We call this condition good health. Of all the things that a human being can inherit from his parents, good health is the most valuable. With good health, life may be an interesting and on the whole a happy adventure. With poor health life may become a burden and a complaint.

Fortunately good health for most people is natural. Most people are born healthy and tend to remain healthy if they use their intelligence to guide their lives. Unfortunately many people who use their intelligence in other matters are stupid or indifferent in the matter of healthful living. They take care of their cars and their bank accounts as if these were the most precious possessions in the world, and at the same time neglect their health, without which no other possession can be fully enjoyed.

You who are studying this book are in a position to avoid the mistakes which many older people have made. Today scientific knowledge about the needs of the body is rapidly taking the place of prejudice and superstition. Indeed we know so much about our bodies that good health for most of us is far more a matter of good sense than of good luck.

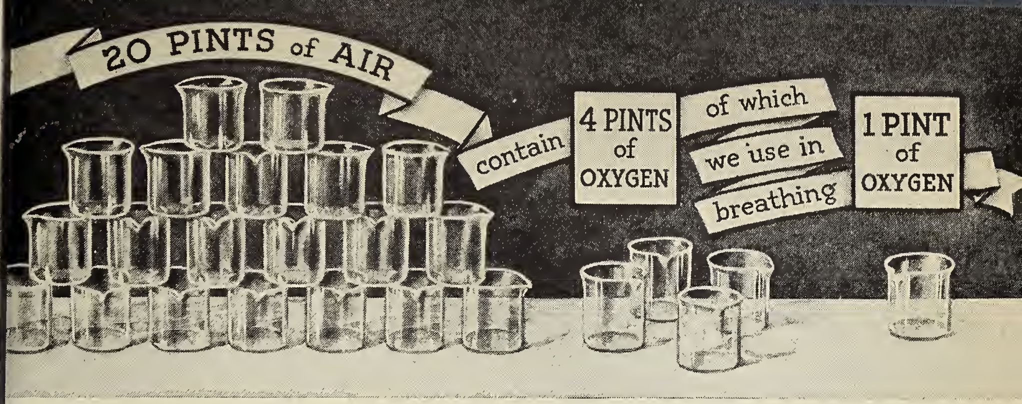
Our Bodies Are More than Machines. At the close of the last chapter you were asked to discuss the statement "The body is often referred to as a machine." Let us discuss it a little further here.

Suppose we compare the human body with a steam locomotive. We can see at once that the two are alike in one important way: *both change the energy of the sun into the energy of motion.* The body takes in the energy of the sun in the form of food, the engine in the form of fuel. As the food and the fuel are used up, more must be supplied if the body and the engine are to go on working. Aside from this similarity, however, the two are very different. The engine must be cared for and controlled by a human being, —that is, by intelligence from *outside* itself. The human body is controlled in part automatically and in part by intelligence that exists *inside* itself.

Food serves at least three purposes. It is used for energy, for growth, and to repair and replace worn or injured cells. Fuel in the engine is of no use except for energy. Machinery does not grow, nor can worn-out parts repair or replace themselves. Only the bodies of living creatures have the power to do that.

The Healthy Body at Rest. Our bodies in health meet the changes of a changing world in marvelous fashion. We can see how they change to meet changing needs by studying the way they work during rest and exercise. Some of the most obvious changes which take place with exercise are changes in the rate of breathing, the rate of heartbeat, the amount of perspiration, and the color of the skin. Following a period of exercise we have feelings of fatigue and thirst. After a short rest we have a feeling of hunger. All these changes which take place in the body during exercise are automatic; that is, they are beyond the control of the mind.

What is the nature of these changes? To understand them let us first study the resting body. While at rest the



Every minute of his life a man strains oxygen from the air in these proportions

average rate of breathing for a man of average size is about sixteen times a minute. In each minute he takes into his lungs about twenty pints of air, or a little more than one pint of air with each breath. Since the air is about one-fifth oxygen, he takes into his lungs about four pints of oxygen in one minute. Of the oxygen entering the lungs, about one fourth gets into the blood and is carried to the cells. Therefore a man at rest uses about one pint of oxygen every minute (see diagram above). It is this oxygen that combines with digested food to produce the energy which keeps the man alive.

Now let us consider the heartbeat of a person at rest. This, like breathing, has an average, or *normal*, rate, as a simple observation will show.

Exercise. How to count the rate of your heartbeat: The heart and the pulse beat at the same rate, and it is easier to count the pulse beat. Place your fingers firmly over your wrist. If you are in good health, you will find that your pulse beats at the rate of about 68 to 75 times a minute while your body is at rest.

The Use of Oxygen during Exercise. Now, for the sake of comparison, make observations on yourself during or immediately following a period of vigorous exercise. Suppose you

take part in a quarter-mile run. You are not conscious of your breathing when the race begins. But after running a short time you become aware that your breathing is very much faster. You soon realize that you are breathing as fast and as deeply as you can. Yet it seems that you cannot get enough air to supply your needs.

A runner in your school may do a quarter-mile in about one minute (the world's record is a little less than one minute). Let us examine this athlete after a race. We may find that he is now breathing at the rate of about fifty times per minute, which is about three times as fast as when he was at rest before the race began. He is also breathing much more deeply than before. The volume of air entering his lungs with each breath is now about three times what it was before the race began.

With about three times as much air entering his body at each breath, and three times as many breaths taken per minute, do you see that the runner's body is using oxygen about nine times as fast as under normal conditions? About nine pints of oxygen reach his cells every minute. This oxygen releases energy nine times as fast as energy was released in the same athlete while he was resting before the race (when, as you will remember, his cells were getting only one pint of oxygen per minute).

Since the release of energy in the human body depends on the oxygen it gets, it is clear that *the rate at which energy is released is greatly increased with vigorous exercise.* Notice that the winning runner pictured on the opposite page seems to

In illness the normal pulse beat of a person at rest is likely to change

Roberts

Keystone View

Vigorous exercise greatly increases the need for oxygen

be panting. We could learn by timing it that a runner's rapid rate of breathing will not return to normal for about twenty or thirty minutes. Is it not clear, then, that vigorous exercise makes a demand for oxygen which is greater than the lungs can supply at the time and that heavy breathing must continue until the need has been met? As a matter of observed fact, a person after running fast *for one minute* must take in oxygen *for twenty minutes* at a several times faster rate than was necessary before the race began.

Exercise. Which do you think is the hardest race: a hundred-yard dash, a mile run, or a Marathon? Why?

How Body Temperature Is Regulated. We all have observed that our bodies produce heat rapidly when oxygen is taken in rapidly. The oxygen which enters the blood during normal breathing releases energy at the rate of 75 kilogram-calories in an hour. (A *kilogram-calorie* is the heat required

to raise the temperature of 1 kilogram of water—about a quart—1° centigrade.) During and following strenuous exercise, energy may be released at a rate of 500 to 750 kilogram-calories in an hour. During exercise heat must naturally be released from the body much faster than during rest. If, however, we had taken the body temperature of one of the athletes shown on page 451 just before and just after the race, we should have found it nearly the same in both cases—about 98.6° F. What is the explanation of this?

Suppose we now count the rate of the runner's heartbeat. After the race his heart is beating about 140 times a minute, twice as fast as before the race. Besides, it is beating harder. We can easily feel the throbbing within his chest. Obviously blood is passing through his heart and lungs at a faster-than-normal rate. The reason for this is that the cells of his body require more oxygen when running than when resting. To meet this requirement the athlete must breathe more deeply and more rapidly to supply the oxygen to the lungs. The blood must move faster in order to carry the increased supply to the cells and in order to carry the carbon dioxide and other waste products away from the cells.

Exercise. Count your pulse beat after you have been sitting for some time. Now do the "standing run" for one minute. Count your pulse beat again. Count your breathing rate. Count these again after five minutes and again after ten minutes. Why were the rates faster after exercise?

Another observation will show that a runner's skin is pink and covered with perspiration. These are reactions of the body which help it to stand the effects of vigorous exercise. *They are reactions for getting rid of heat.* Since

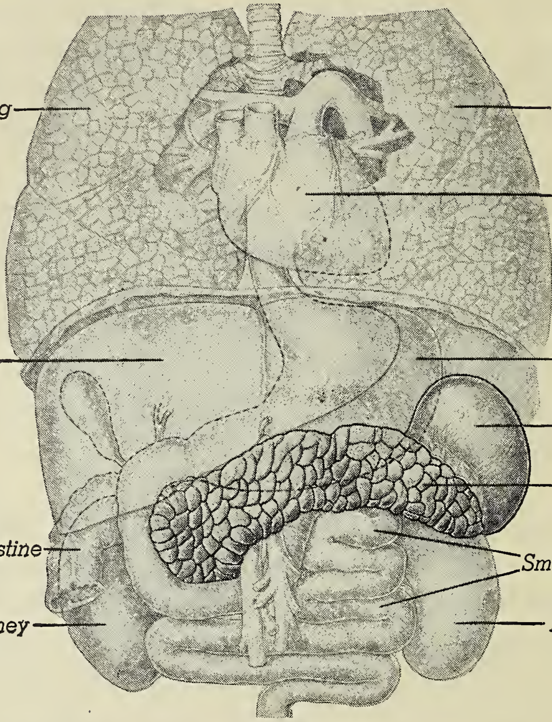
heat may be produced in the body several times as fast during exercise as during rest, it must also leave the body several times as fast. The pink color shows that more blood than normal is circulating in the capillaries which lie just beneath the skin. When near the surface the blood loses heat more rapidly by radiation. In this way some of the extra heat is lost.

How does perspiration help to get rid of heat? You have already seen that perspiration is a means of getting rid of waste. You have probably also learned that *evaporation is a cooling process*. Perspiration evaporating from the skin is therefore an effective means of getting rid of heat and of helping to keep the temperature of the healthy body always about the same.

How the Glucose in the Blood Is Regulated. In addition to the need for an increased supply of oxygen in the cells during exercise, there is a need for an increased amount of food. Carbohydrates are stored in the liver, and as they are needed for energy they are released to the blood in the form of glucose. Under normal conditions there is about one part of glucose in the blood to every thousand parts of blood. In order to keep up this supply in the blood during exercise, additional quantities must be released to the blood from the liver. A fine regulating mechanism takes care of this task because even during strenuous exercise the concentration of glucose in the blood is kept at about one part in a thousand.

How the Circulation Is Regulated. There are other fine adjustments in our bodies which exercise reveals. When there is more blood at the surface of the body, there must be less blood underneath. The *spleen*, an organ lying near

the stomach, is a sort of blood storage tank. The location of the spleen is shown in the diagram below.

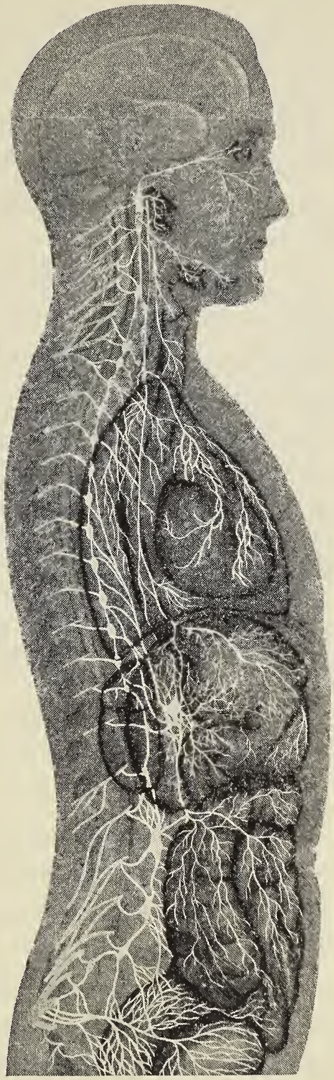


The spleen is a storage tank which helps to regulate the circulation of our blood

Normally the spleen holds about one quart of blood. During vigorous exercise about two thirds of the blood in the spleen is squeezed out. The volume of blood in the liver, the kidneys, the stomach, and the intestines is also less during exercise than at other times. This is one of the reasons why *it is best to rest for a while after meals* before starting heavy work or vigorous exercise. Do you see why?

The Teamwork of Our Organs. All these various processes work together. When the need arises, the rate of our breath-

ing and the rate of our heart action increase. The capillaries near the surface of the skin are enlarged, and more blood flows through them. At the same time blood is forced out of some of the internal organs. Food that has been stored in the liver and in other parts of the body is released and carried by the blood to the cells. All these processes not only work together, but they also work without any conscious direction on our part.



The job of the nervous system (shown in white) is to keep all parts of the body working in harmony[1]

The Nervous System. It seems remarkable that the working of the human body is largely automatic, but life as we know it would be impossible if this were not so. Living processes are under the control of the *nervous system*, a network of delicate fleshy strings which spread through the body and connect with the brain. At the right is a diagram of the nervous system. Its business is to keep all parts of the body working in harmony.

In all cases of vigorous exercise and heavy work, the nervous system works without any

[1]From Andress, Goldberger, Hallock, *Safe and Healthy Living.*

direction from the brain. In other words, we do not have to think about breathing faster, circulating our blood faster, and all the other things which are necessary when we change from a condition of rest to a condition of exercise. In many other ways (in regulating the digestion of food, for example) the nervous system relieves the brain of work.

The brain, though part of the nervous system, is thus able to tend to other things. It can think about and plan and direct many other kinds of activities. If his brain had not been free to do this, primitive man would never have been able to grow civilized. Modern man would not be able to enjoy all the things that make life worth living because he would be too busy just keeping his heart, lungs, and the rest of his body at work.

THE ENEMIES OF GOOD HEALTH

The Immediate Effects of Alcohol. We have seen that the human body is adapted to use carbohydrates, proteins, fats, certain mineral salts, water, and air. Other substances taken into the body may tend to disturb the smoothness with which it works. Such substances as alcohol and tobacco smoke are enemies of good health, for reasons which we shall now examine.

In every nation and from earliest times the evil effects of drinking alcohol have been recognized. Many modern studies have been made on the effect of alcohol on the human body. The amount of alcohol in the blood can be measured. Careful studies show that when alcohol in the blood reaches only one hundredth of 1 per cent the average person feels that his breathing is freer. He feels a mild tingling in his mouth and throat.

National Safety Council

lcoholic liquor is a grave menace in such an emergency as this because it slows down a driver's response to danger

When the concentration reaches five hundredths of 1 per cent, the average person begins to show some unsteadiness. He is apt to feel fine, however,—as though he were in the best of condition and able to tackle anything or anybody. A person in this stage of drunkenness is apt to be an annoying neighbor in a streetcar or a railroad train. He may act on the spur of the moment and fail to observe the standards of social custom. When the concentration reaches one tenth of 1 per cent, the average person staggers, talks to himself, sings, and becomes a nuisance in general. He has lost control of his own behavior. He is, in simple language, thoroughly drunk.

Alcohol and the Automobile. The seriousness of drunkenness in the modern world does not lie in the annoyance it may bring to sober people. It lies in the death it may bring to innocent people. Look at the photograph on page 457. If you are an average sober person driving an automobile, it takes about three quarters of a second for you to start to put on the brakes in such a situation as this. *If you are going 40 miles an hour, your car will travel nearly 44 feet before you can even start to bring it to a stop.* It will travel perhaps 164 feet before you can bring it to a complete stop.

Now alcohol in the nervous system slows down a driver's response to danger. Scientific tests have shown that a man with alcohol in his blood may be a great menace on the highway for this reason. The slow response of the nervous system continues for from two to four hours after drinking even moderate amounts of alcohol. Unfortunately neither the moderate drinker nor anyone else may be aware of any change in the drinker's power of response. Not only this, but the effects of alcohol vary so much among different people that an amount which has little or no effect on one person may very seriously affect the activity of another.

A famous student of physiology and nutrition has this to say to the automobile driver: "Moderate user, keep off. For at least four hours after a dose of alcohol formerly considered 'permissible,' you, as a motor-vehicle operator, may well be considered a 'menace to society.'" In the words of the man in the street, "Alcohol and gasoline don't mix!"

Alcohol unfits people for work that requires skill

Galloway

Some accidents in which drunken drivers are involved are slight, but many result in death or serious injury. Furthermore there is no way of knowing how many accidents have been caused by drivers whose nervous systems contained enough alcohol to make them think and act too slowly for the emergency, but not enough alcohol to give any outward sign of drunkenness.

Alcohol and the Skilled Workman. Not only is the automobile-driver affected, but the usefulness of the skilled worker is lowered by even small amounts of alcohol. Repeated experiments have shown this to be true. Tests have been made in such skills as typewriting, marksmanship, and many other types of activity.

Railroad companies will not knowingly hire a drinking person for a position connected with the operation of trains. Too many lives are in the hands of railroad employees, and it is not safe to take any chances where human life is concerned. All tests show that the worker who is under the influence of alcohol makes more errors than the worker who is not. The slightly intoxicated worker himself, however, usually feels that he is doing very well, perhaps even better than usual.

The Effect of Heavy Drinking. From what we have already learned it is clear that the body under the influence of alcohol is not a healthy body. An athlete under the influence of alcohol would have a poor chance of winning a quarter-mile race. He might not only lose the race but also severely damage his health.

The discussion so far has chiefly concerned the moderate drinking of alcoholic beverages. The harmful effects of heavy and continuous drinking are well known to almost

everyone. The weakening of the body (especially the liver and the kidneys) is an often-observed result of such drinking. Physicians know that heavy drinkers have much less than an average chance of winning in a battle with such a deadly opponent as pneumonia. On the whole, the length of life is definitely shortened by heavy drinking, even if practiced only once in a while.

Alcohol and the Machine Age. If this were not an age of machines, the alcohol problem would be merely a personal problem. But in our complex civilization keenness and quickness of judgment are needed at every turn. This being the case, even the moderate use of alcoholic drinks makes a serious *social* problem. In this modern world the bookkeeper who uses calculating machines is apt to make more errors, the man who crosses a crowded street is more likely to land in a hospital, and the man who drives an automobile is more likely to take the life of someone else if there is alcohol in his blood than if there is not.

Exercise. Read Haven Emerson's *Alcohol: Its Effects on Man* for a fair and thorough scientific discussion of the alcohol problem. Write a report on the social effects of alcohol. Base it on reliable information. Ask your teacher to help you select the best authorities.

The Case against Smoking. Tobacco, like alcohol, affects the normal working of the body. There is no doubt that too much smoking is harmful. It is difficult, however, to say what "too much" smoking is, because tobacco, like alcohol, affects different people differently. There are some people who seem to be seriously affected by what seems to be moderate smoking. Anyone who experiences dizziness or other unpleasant effects after smoking should never smoke.

Smoking injures chiefly the heart, the throat, and the nervous system. When you see so many people using tobacco, you may think it is not harmful. But there are several things that may truthfully be said against the use of tobacco, and little that can be said in favor of it. The first-hand observations of athletic coaches and trainers have convinced them that tobacco-users do not ordinarily make good athletes.

No physician would say that tobacco is as poisonous as alcohol, but it is poisonous enough to be avoided by anyone who really values his health. Smoking has undoubtedly been blamed unfairly for many diseases; yet few physicians would deny that smoking is often to blame for the following conditions:

1. Heart disturbances which are marked by irregularity of beat and shortness of breath, sometimes called "smoker's heart."
2. Inflammation of the upper air passages which is marked by hoarseness and a dry cough, sometimes called "smoker's throat."
3. Many disturbances of the nervous system which reduce the feeling of well-being and the efficiency of the victim.

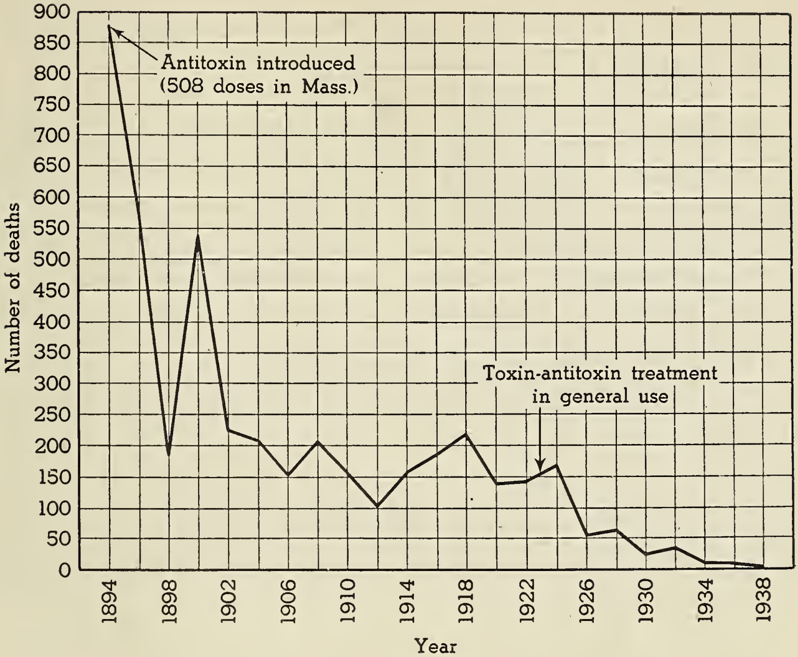
In a recent investigation of tobacco-users by Dr. Raymond Pearl of Johns Hopkins University, it was found that the smoker, even though he smokes only a few times a day, dies sooner than the average nonsmoker. Why, then, should anyone smoke? The answer is that smoking, like any other habit, once firmly established, is hard to break. The time to deal with the habit of smoking is before it is ever formed. It is much easier to conquer it then than later.

Exercise. Read the appendix on tobacco by Dr. Emil Bogen in Fisher and Emerson's *How to Live* (Twentieth Edition, 1938). This will give you a thoroughly fair and up-to-date answer to the question "What harm is there in smoking?"

The Use of Drugs as Medicine. Among the substances that people frequently take into their bodies are drugs which are used as medicine. When you go to a physician you expect him to give you a pill, but skillful modern physicians are getting away from the reckless use of pills. When you are ill, your body is not working normally. *The wise physician knows, however, that your body tends to return to normal of its own accord if given half a chance.* He knows that the best treatment for most illnesses is rest and protection from exposure.

There are certain germ diseases which medicine can undoubtedly help the body to fight. Vaccination, for example, increases your protection against smallpox. It has made this serious and once widespread disease no longer a grave menace to civilized society. Similarly, the toxin-antitoxin treatment strengthens your protection against catching diphtheria, and antitoxin helps to cure it after you have caught it. There are other antitoxins that are effective in the treatment of typhoid, tetanus, and hydrophobia. The graph on the opposite page shows clearly what humanity owes to medical science for help in fighting one of these diseases.

Malaria is a disease which is caused by germs that get into the blood and destroy the red blood cells (the cells that carry oxygen through the body). The drug quinine is a poison to these germs, and taken according to a definite schedule, it will cure malaria. There are a few other ill-



The history of diphtheria in greater Boston shows clearly the value of the antitoxin and the toxin-antitoxin treatments of this disease

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nesses that may be cured by treatment of this sort, but the treatment must be directed by a skillful physician.

Exercise. Make a study of a dozen common drugs and medicines used by a modern physician. Find out their particular uses and value. Make a chart of your findings.

Prescribing medicine for oneself is generally dangerous. It is safest to avoid the habit of taking medicine and to acquire the habit of depending upon the body to correct its own minor ailments. The use of drugs is just as likely to hinder as to help the body return to normal. When suffering from a minor ailment, avoid fatigue and protect

yourself from exposure. In case of more severe illness, seek the advice of a capable physician.

Exercise. Look through some of the newspapers and magazines that come to your house and see how many advertisements they contain of so-called "remedies" which you think might be either worthless or definitely harmful. Do any of the radio programs advertise such "remedies"? Why do you think newspapers, magazines, and radio stations accept such advertisements? What can you do to make up for the results of such advertising?

RULES FOR HEALTHFUL LIVING

It is better to avoid illness than to cure it. It is also, in most cases, easier. Since our bodies tend to be healthy if we let them, the rules of healthful living are comparatively few and simple. From what you have learned in this chapter and from what you already know, it should be easy for you to form habits now which in later life will bring large returns in health and happiness.

The Rules of Eating. We are all, to a large extent, what we eat. Both experiment and experience have shown that, for the average person, simple natural foods are more healthful than complex artificial ones. Milk, for example, is more healthful than ginger ale, and whole-wheat bread is more healthful than lemon meringue pie. Milk, eggs, butter, some meat (but not too much), vegetables, fruits, and cereals should be the chief items in your diet. Properly combined, they contain all the elements that your body needs. Eat these foods slowly and without stuffing, and your body will do the rest.

Acme

Health depends to a large extent on what we eat and drink

Exercise. Keep a three-day record of what you eat. Did any meal "disagree" with you? If so, try to explain why. At the end of the record list those foods which you might better not have eaten, and give the reasons.

The Rules of Cleanliness. Cleanliness and proper eating are closely related. We have already seen that the body should be kept clean of harmful substances such as alcohol and tobacco. It should also be kept clean of decaying food materials. The teeth should be brushed at least twice a day, morning and evening, and should be cleaned by a dentist twice a year. The bowels should move once a day, preferably in the morning.

Baths should be taken frequently to clean the skin of waste which gathers from inside the body and filth which

gathers from outside. Warm water and soap should be generously used. At the end of a bath, the body may be splashed with cold water, which stimulates the circulation and makes you feel well. Drying should be done vigorously with a rough towel until the skin is warm and pink.

Exercise. How many baths, on the average, do you take in a month? Do you think you bathe often enough and in the correct way?

The Rules of Breathing. Breathing will take care of itself, but the kind of air which is breathed is partly a matter that must be arranged. Everyone should breathe outdoor air at least an hour a day, and several hours if possible. In Chapter Twelve you learned about the need of proper humidity, temperature, and ventilation in your house. It might be well to read that chapter again.

Part of the business of breathing, as we have seen, has to do with the regulation of body heat. Our clothing also has to do with this. The usual practice of civilized man is to pile on more clothing when his body feels cold. The result, in many cases, is that the skin is robbed of air and light which it needs. Many people forget that their bodies as well as their houses need ventilation.

Clothing should be porous and light if the skin is to remain healthy. It should not be too tight at any point because binding interferes with the circulation of the blood. Much can be done to train, or "harden," the skin, but it should be done with the greatest care.

If you have been wearing so much clothing that your skin has lost its power of adaptation to changing weather conditions, you should begin to wear less. But *you should not begin to do so in winter*, because this might bring on a bad cold or even pneumonia. The time to begin training

Good food makes good health

the skin is in summer when the air is not too cool. Expose your body to the air and light, and gradually increase the length of exposure *as long as the reaction is a warm one.*

Once your skin has become accustomed to air and light, you will not need so much clothing as before. You will find that your body will stay warmer and more comfortable than it did when you wore heavier and less porous clothing. You will find that you have fewer colds and that you feel better generally.

Exercise. Take stock of your clothes. Are they heavier or lighter than those of your companions? Can you see any connection between the kind of clothes you wear and how you feel, and if so, what?

The Rules of Body Activity. Our bodies are built for action, and they should be held in such a way as to further the working of the internal organs which make activity possible. We all have heard that it is well to stand, walk, and sit erect, but few of us really do it. Civilized man tends to stoop when he walks and to slouch when he sits down.

Summer clothing helps accustom the skin to air and light

Harold Lambert

The way we carry our bodies is described as our *posture.* Good posture is a valuable habit to form, and an easy one. "Head up, chest out, stomach in"—how often have we heard this advice! Many people who suffer from headache, constipation, nervousness, cold hands and feet, and many other unpleasant conditions might get rid of their

troubles if they heeded this advice. Without good posture the lungs and digestive organs are squashed, and naturally cannot do their work well.

Work and play are the most common forms of bodily activity, but there are few rules that apply to these activities in all cases. One rule, however, should be observed by everyone who wants to be healthy. *Work and play should be properly balanced by rest and sleep.* The harder you work and play, the longer you should rest and sleep. Add to this the rule of avoiding such unhealthful emotions as worry, anger, and fear, and your list of health rules is complete.

Exercise. Keep a three-day record of your activities, marking the hours of work, play, rest, and sleep. Do you believe they were properly balanced, and if not, what changes would have been wise? How was your walking and sitting posture during the time of observation? How was your emotional health?

How does your posture compare with that of these Balinese women?

James Sawders

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Good health is more a matter of good luck than of good sense.

2. Your body and a steam locomotive are exactly alike because both change the energy of the sun into the energy of motion.

3. The only purpose of food is to supply the body with energy.

4. Due to the regulating machinery of the body, we need no more oxygen when we are running than when we are walking.

5. Perspiration is a very effective means of conserving heat.

6. The best time to exercise is right after meals because then we have most energy from our food.

7. Breathing, the circulation of blood, and the digestion of food are all beautifully regulated by the brain.

8. Moderate drinking of alcoholic beverages is never harmful in any way.

9. The fact that so many people smoke proves that smoking is not harmful.

10. It is better, as well as cheaper, to prescribe for one's own minor ailments than to seek the advice of a physician.

11. Civilized man is probably healthier than was primitive man because he does not have to eat food in its crude natural condition.

12. Clothing provides the only means of regulating the heat of the human body.

Questions for Discussion

1. Sometimes you hear people say of an athlete that he is "burned out." What is meant by this? Do you think it is a good term?

2. Make a list of things you believe people ought to remember about alcohol and tobacco. Discuss this list with your classmates. Perhaps they will make similar lists. If so, the discussion can be devoted to criticizing each other's lists.

3. Do you think the government should regulate the manufacture and sale of patent medicines? Why?

Things to Do

1. Investigate and report on the food and drug regulations. After you have studied the conditions as they now exist in this country, write a model law for the regulation of the patent-medicine industry.

2. Many books have been written about fake remedies and how they endanger human life. An easy one to read is Kallet and Schlink's *100,000,000 Guinea Pigs*.

3. Get figures on the decrease of typhoid fever in your city, county, or state, and make a graph similar to the graph for diphtheria on page 463.

4. Write a report entitled "My Health and What I Do to Preserve It." Make it personal and include any habits which you consider especially beneficial.

U N I T   S I X

CONSERVATION

IN A

CHANGING WORLD

In the earlier units of this book we have studied many of the changes of an ever-changing world.

In the preceding unit we have just learned how life and health depend on the proper use of energy and materials which the changing world supplies.

The *use* of energy and materials, however, is only part of the problem of living.

Preservation of energy and materials is also a very important—and a very much neglected—part.

Wild life, forests, minerals, soils—all the natural resources on which human life depends—are rapidly being laid waste.

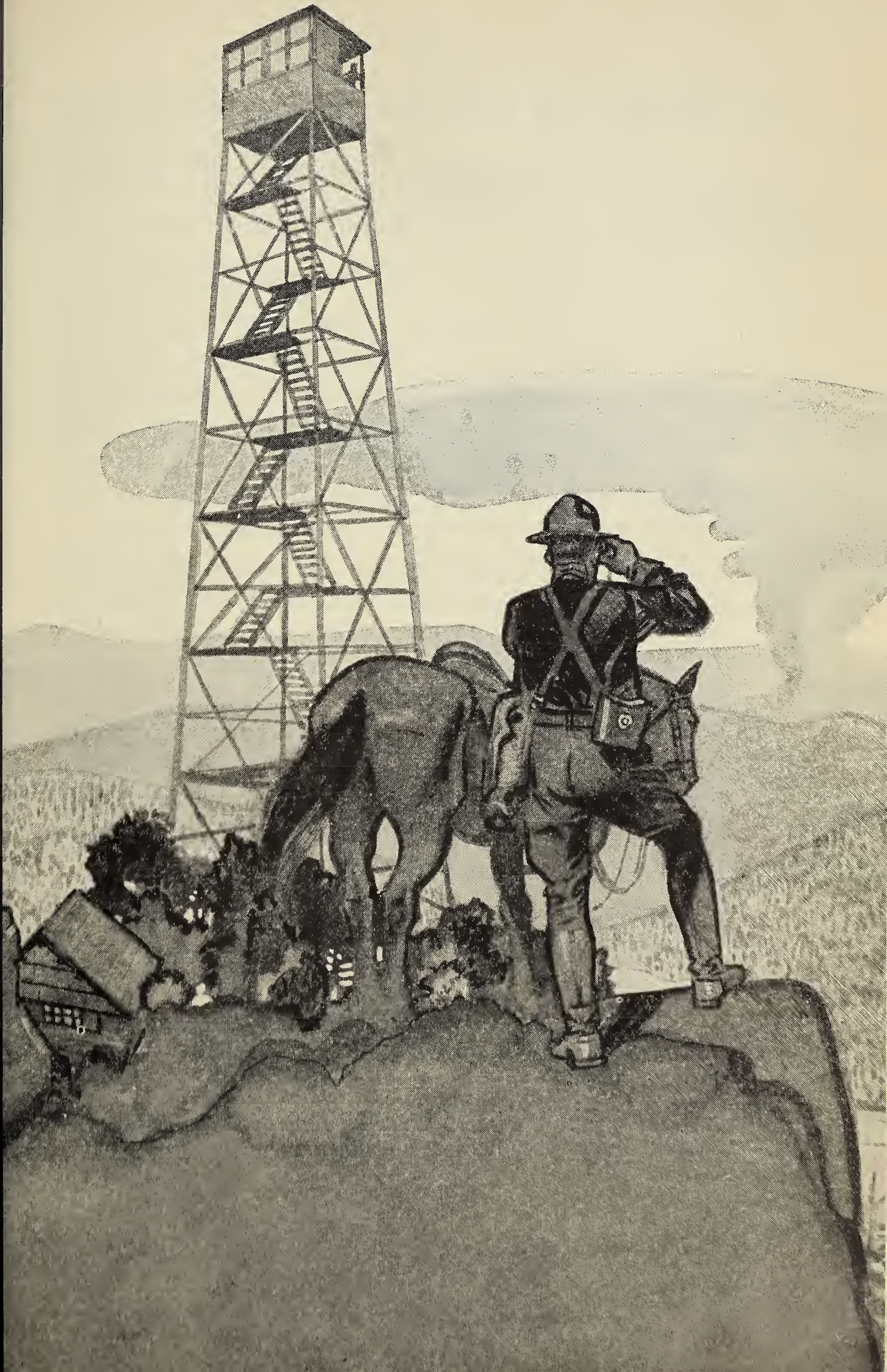
Only recently have people in general waked up to the fact that "something must be done about it."

Only within the last few years have they realized that something must be done on a very large scale, and done at once.

How can we use and yet not abuse the natural wealth of the earth?

In this final unit let us see if we can find the answer to this gravest of questions.

Let us see if we can discover how the forces that tend to destroy the beauty and bounty of the earth may themselves be destroyed.



CHAPTER EIGHTEEN

How Can We Save Our Plant and Animal Resources?

THE NEED FOR CONSERVATION

Small-Scale and Large-Scale Conservation. *The preservation of natural wealth is called conservation.* Everyone knows in a general way that wastefulness is a harmful and foolish trait. Most everyone practices certain economies for the simple reason that extravagance often brings suffering. Every day of our lives we all practice conservation on a small scale, as a few simple illustrations will show.

When you wear holes in your stockings, your mother does not throw them away. She mends them and thus conserves them for future use. When the vegetable garden and the orchard yield more food than can be eaten at once, the thrifty housewife cans the vegetables and makes jelly or "conserve" of the fruit. When you put milk in the refrigerator, you practice conservation of food. When you rest after play, you practice conservation of energy (bodily strength). When you walk instead of taking an automobile, you practice conservation of gasoline and oil.

Exercise. Recall what you did yesterday and make a list of all the ways in which you practiced conservation.

Unfortunately our economies apply chiefly to little things. As a nation we have been spendthrifts. We have laid waste some of our most valuable possessions. As we shall see in the course of this unit, conservation on a large scale is one of the most desperate needs of our time.

Travel Magazine

Before civilization all but stamped them out, herds of bison were common on the Western plains of North America

What the White Man Found in America. Some three hundred years ago, when white men were beginning to build their homes on the shores of this continent, red men were living the simple lives of their ancestors over all the rest of the land. Nobody knows how many thousands of years the red man had been in America before the white man arrived. We only know that he had been there a very long time and that in all that time he had lived in peace with his land.

We know that the country which the white man slowly wrested from the red man was everywhere rich and beautiful. Nowhere was it scarred by foolish or greedy acts of men. Rich soils which had been slowly accumulating from the weathering of the rocks through untold ages were practically undisturbed. Mighty forests and grasslands held the earth in place and made homes for multitudes of wild animals. Rivers flowed clear and pure. Beneath the surface the pores of soil and rock held water like a sponge, and supplied unfailing nourishment to the life above.

What the White Man Did to America. If you drive across America in an automobile today, you will find it still a rich and beautiful land. But if you do not drive too fast, and if you observe and think as you move along, you will realize that America has greatly changed in three hundred years. Ugly gullies scar its face in many places, and rivers are thick with mud which was once rich soil. The noble old forests have almost entirely vanished. In their places are thin little "second-growth" trees—where there are any trees at all. In the Far West grasslands are still abundant, but the grasses are thin and weak compared with those through which the bison roamed. Large wild animals are so rare that if you see a deer or a bear along the road, you are greatly excited. How were these unhappy changes brought about?

Exercise. Make a careful survey of the region around your home. Try to imagine what it looked like before white men came to live there. Study the trees, pastures, soils, streams, and wild life, and try to decide where and how the land has been abused. Try to decide what might be done to improve conditions.

The above exercise will take some time to complete. As you work on it you will go ahead with your study of this unit. You will learn the different ways in which white men have abused and wasted the natural wealth and beauty of America. You will also learn many ways of improving conditions, some of which can probably be applied to your own region.

THE CONSERVATION OF WILD LIFE

The Disappearance of Fish and Game. Records left by the early colonists and explorers tell of a land that teemed with fish and game. Deer, elk, moose, and bears were common

U. S. Forest Service

Wild turkeys were once abundant in North America

in all the forests from the Atlantic to the Pacific. Beavers, otters, and minks swarmed in the streams, wild sheep and goats in the mountains. Antelopes grazed in great herds on the plains. The hoofs of bison thundered from Tennessee to the Rockies, and from northern Canada far into the Mexican plateaus.

The bird life of America was particularly abundant. Wild turkeys, swans, and grouse were everywhere. Ducks and geese moved through the sky during spring and fall in all-but-endless battalions. Passenger pigeons actually darkened the sun with their wings.

Fish life was equally abundant. During the season of migration salmon were so plentiful that they were pitchforked out of the rivers of the Pacific coast and thrown on the fields for fertilizer. Shad were equally plentiful in the rivers of the Atlantic coast. Multitudes of trout lived in

the cooler lakes and streams, and the mighty sturgeon held sway throughout the vast spread of the Mississippi.

All this is changed today, as any boy who has ever gone fishing or hunting knows. The passenger pigeon is entirely extinct. The sturgeon and bison hang on to life by a thin thread. Wild turkeys and certain other game birds are extremely rare in most places. Though fish and game may still be taken throughout America, the sportsman must generally work harder for a rabbit than his ancestors did for a deer.

Fishermen and Fish. When we try to understand why fish, for example, are no longer so plentiful as they once were, we are likely to blame the fisherman. The Indians fished with spears, lines, and small nets, but they never took more fish than they needed for food. Scientists believe that there were never more than about one million Indians in America north of Mexico at any one time. This relatively small number of people could eat fish at every meal without making any impression on the population of fishes which America once supported.

When white men came in increasing numbers, the demand for fish increased. Primitive methods of fishing gave way to more efficient methods. Great nets and traps were laid to catch such fish as salmon and shad as they swam up the rivers from the sea. In the sea itself commercial fishermen have taken millions and millions of tons of haddock, cod, and other marine fishes with small-meshed nets that capture the small as well as the large individuals. In this way, and through modern refrigeration, which enables a fishing boat to trail a school of fish until every fish is taken, commercial fishing has sadly reduced the natural wealth of our waters.

Fresh-water lakes and streams which once were the home of billions of trout, bass, pickerel, and other fishes have been seriously overfished. Seining, blasting with dynamite and lime, taking female fish before they have laid their eggs, have all contributed to the national slaughter of our food and game fishes. Fortunately a great many of these evils have now been corrected by law. Methods of fishing which make a serious drain on the natural supply are illegal. It is the duty of the Bureau of Fisheries and the various state Fish and Game Commissions to maintain and to increase, if possible, the fish population of our American waters. On the whole they are doing a very good job.

Exercises. Write to the Fish and Game Commission of your state for a copy of the laws which regulate the taking of fresh-water fish. Study them and make a report on the conservation methods used by your state to preserve its fish population.

If there is a fish hatchery near your home, visit it and make a report on how the lakes and streams of your region are restocked with food and game fishes. If you cannot visit a hatchery, write to your State Fish Commission for information.

You may be surprised to learn that the worst enemy of fish life is not short-sighted and greedy methods of fishing. Other abuses of our waters have taken a far greater toll in fish, as we shall see in the following paragraphs.

Fish hatcheries are helping to restore the fish population of American waters

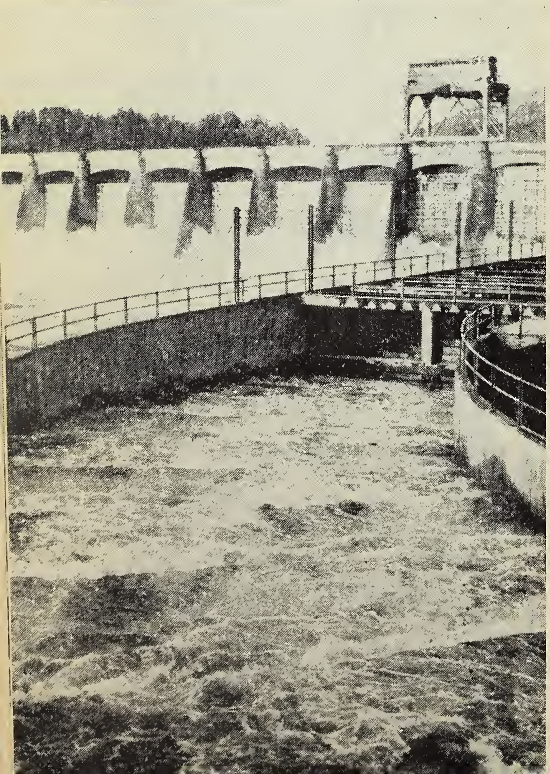
Sawders

The Menace of Barriers across Streams. Salmon and shad, which live in the sea and enter fresh-water rivers only to lay their eggs, are among the most valuable food resources of America. Before the white man built dams and other barriers across the coastal rivers, these fishes swarmed in the streams as well as in the outer ocean. But as water power was developed, it became more and more difficult for the fishes to get over the dams to the spawning beds. More and more of them died in the desperate attempt to reach the places where some strange instinct demanded that their eggs be laid.

Today when a fisherman catches a salmon in the Penobscot River of Maine, his exploit is noted in the newspapers. And the Penobscot was once one of the finest salmon rivers on earth! The same is true of most other streams on the Atlantic coast, not only for salmon but also for shad. The Pacific coast rivers, which are still rather generally unharnessed, still have large runs of salmon. Fortunately we are now awake to the danger of barriers in such streams. The photograph at the left shows the elaborate system of fish ladders which has recently been built over Bonneville Dam on the Columbia River. Through such devices as these fish can ascend the rivers to lay their eggs almost as easily as if no dam existed.

These fish ladders at Bonneville Dam in Oregon were designed to help salmon ascend the Columbia River to lay their eggs

U. S. Bureau of Reclamation



The Menace of Pollution. By far the greatest enemy of all water life is pollution of the water. Manufacturing has come to the banks of nearly every large stream, and pollution has come with it. The vile and poisonous waste of numberless industries is dumped into the once clean and beautiful rivers. No wonder the fish have died!

Not only this, but it is estimated that the sewage from about forty million people is discharged into the streams, lakes, and coastal waters of the United States *without any treatment whatever*! The effect of this vicious practice is widespread. Every living creature that touches these waters is apt to be poisoned, man no less than oysters, ducks, and fish.

Exercise. Make a study of the pollution of the largest river in your state. Write to the boards of health in the large towns or cities along the river for information about pollution and the measures which have been taken to fight it. After you have gathered your facts, write a report on what causes pollution of the river and what measures might completely eliminate it.

The control of pollution is more a social than a scientific problem. Where a river is used by the people of many villages, towns, and cities, perhaps by the people of three or four states, nothing that any one group can do alone will be of much value. The fight against pollution must be a large-scale undertaking.

Unfortunately in this country the fight has hardly begun. In the rivers of some of the most highly industrialized regions of Europe, however, there is no serious pollution because the people have banded together to avoid it. Here in America we could do likewise if enough of us were determined to have it that way.

Underwood & Underwood

These "game hogs" look proud, but they should be ashamed

Why Land Animals Have Become Scarce. The story of the slaughter of wild life does not stop with the water. As more and more people settled in America, there was naturally more and more drain on the animal resources of the dry land. As the railroads opened the regions to the west, market hunters followed and ruthlessly murdered the game. Settlers with their axes and barbed wire cut down forests which gave protection to many wild creatures and fenced the range on which the antelope and bison grazed.

It was perhaps unavoidable that as civilization closed in on America many wild creatures should go. We are waking up to the fact, however, that many have needlessly died —and are still needlessly dying. Hunters have killed for the sheer love of killing, and have left their victims to rot where they fell. The natural breeding grounds of wild animals, particularly game birds, have been needlessly destroyed.

The photograph below shows a marshland area which provides food, protection, and a breeding place for millions of wild fowl and many fur-bearing animals. Such marshes must be preserved if we do not want our ducks and geese to follow the passenger pigeon to extinction. Many marshes of this sort have been drained for commercial purposes with serious injury to many species of plant and animal life.

Fortunately the Biological Survey and the Forest Service, as well as many similar bureaus in the various states, are fighting to save what wild life remains and to increase it wherever possible. National forests and parks, state parks, bird refuges, and strict game laws are furthering the cause of conservation throughout the land.

Exercise. Find out what your state has done to preserve the fur-bearing animals and birds of your region. What could be done toward this end which has not been done?

[M]arshlands such as this are absolutely necessary for the preservation of wild fowl

U. S. Bureau Biological Survey

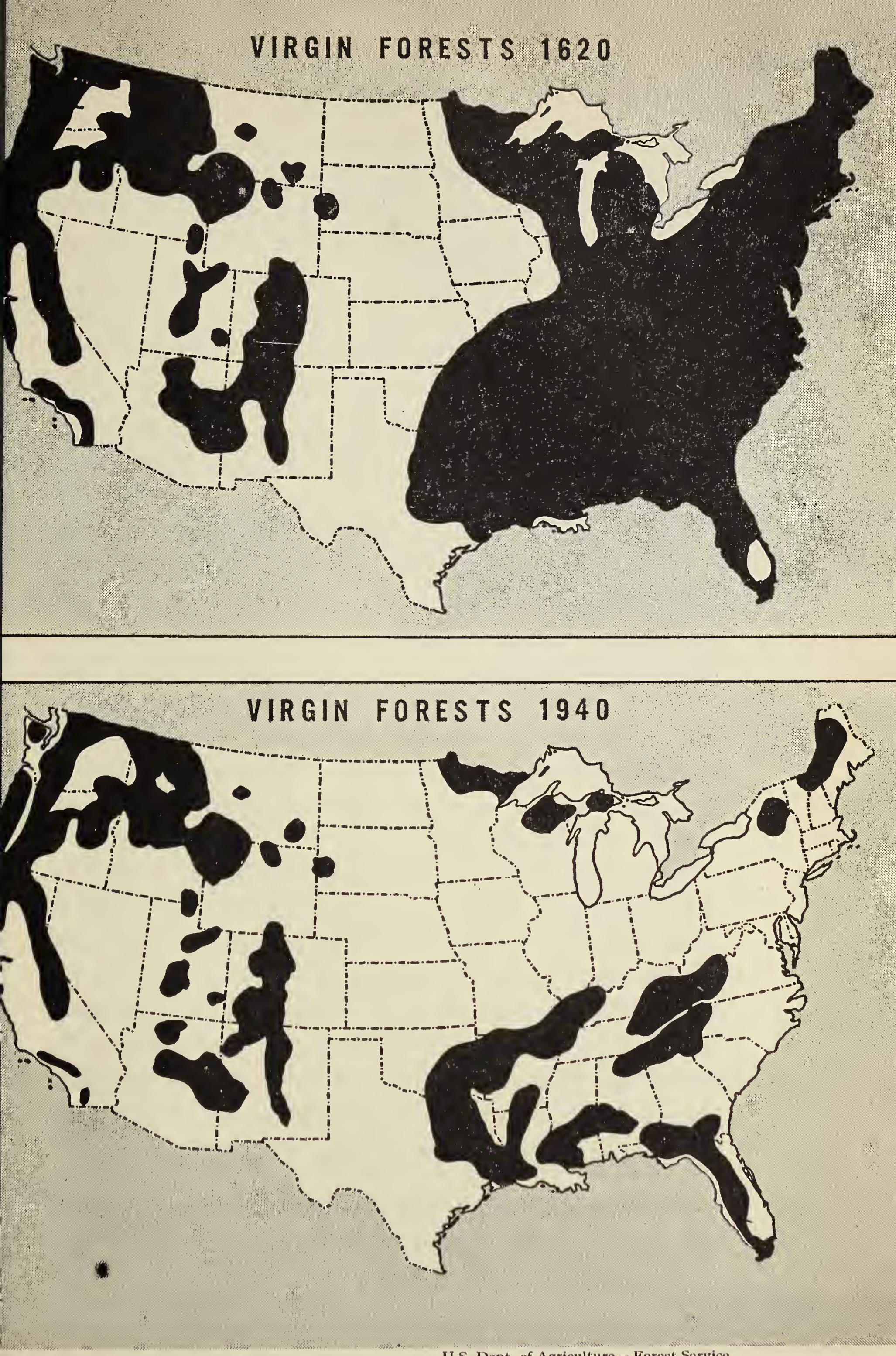
THE CONSERVATION OF FORESTS

Our Vanishing Forests. When the Pilgrims settled at Plymouth in 1620, nearly half the United States was covered with forests. Some eight hundred and fifty different kinds of trees grew in these forests. Birch, beech, maple, and pine trees stretched in unbroken stands from Maine to Florida, and merged with oaks and hickories farther west. On the other side of the central grasslands, a variety of evergreens covered nearly the entire Rocky Mountains, and spruces, firs, and redwoods carpeted the Pacific coast. The map at the head of the opposite page shows the extent of our forests when the Pilgrim Fathers arrived.

In 1940 these virgin forests had been reduced to less than one eighth their former size, as the map at the foot of the opposite page shows. No more tragic illustration of change in our changing world can be had than this process of *deforestation.* In three hundred years the white men who settled in North America have destroyed some of the finest forests on earth. Let us see why they did so.

The Early Colonial Ax. Many of the Englishmen who first colonized New England had been too poor to buy wood for fire in their native land. England's forests were all but used up, and wood brought in from other lands was expensive. The colonist who landed in America found wood at every hand—a paradise of plenty. He did not spare the ax.

As early as 1631 a sawmill was producing lumber in New England and sending some of it to Europe. Soon sawmills were buzzing along the coast from Massachusetts to Virginia to meet the rapidly growing need for lumber. Thousands of wooden ships were built, and hundreds of



U.S. Dept. of Agriculture — Forest Service

This is what the white man did in three centuries to the forests of the United States

thousands of wooden barrels for the rum trade which the colonists carried on with the West Indies and England. In 1681 William Penn became alarmed at the rapidity with which the trees of Pennsylvania were disappearing. He ordered that one acre of forest land be left for every four acres that were cleared. This order, however, was a very soft note of conservation amid the deafening buzz of the sawmills.

Exercise. Read up on colonial history and make a list of the wooden articles which were used in colonial times.

The Ax Moves West. As colonization spread westward, the forests continued to fall. The first need of a pioneer settler in a wooded land was a clearing on which to grow food for his family. Then, too, hostile Indians lurked in the forests of America, and clearings had to be large enough so that in case of attack the settler might see his attackers. For one reason or another the forests were considered enemies of advancing civilization. Accordingly civilization advanced by hacking down the trees and without any thought of replacing them.

The fertile farm lands of Ohio, Michigan, Wisconsin, and Minnesota were won at the expense of the forests. Many of the trees that escaped the farmer fell prey to the lumberman. Lumbering halted for a time in the region of the Great Lakes, but then jumped over the grassy prairies and took up the butchery again in the mountains of the Far West. Today this industry is busy in Washington, Oregon, and California—destroying the last of our virgin forests (see photograph on the opposite page).

The Wrong Way to Use the Forest. "All this is too bad," you may say, "but people need farms and wood. They

U. S. Forest Service

On the Pacific coast the last of our virgin forests are being destroyed

cannot have farms and wood without cutting down trees." True, but there are right ways and wrong ways of using our forests. The right ways may be learned through study of the forests and our needs.

Forests are not like mines. They do not have to be destroyed as a natural part of their development. Owners of timber have generally thought only of making as much money as possible as quickly as possible. They have generally cut down all the trees in a given area which could have any possible use. In doing so they smashed the saplings that might have reforested the area. They left the branches on the ground to await the lightning or some careless camper's fire.

Forest Conservation. Though we are still destroying trees at an outrageous rate, we are also trying to save our forests. Even the lumbering industry has found it profitable to

practice forest conservation. By cutting only the mature trees, by clearing away the "slash" (which is a great fire hazard), and by reducing the waste which has always attended the logging and milling of timber (and which still accounts for about 62 per cent of every marketable tree), many private lumber companies are attempting to keep alive the goose that lays the golden eggs.

Even so, many trees are being cut which should be allowed to stand. The illustration on the opposite page shows two lumbermen in the act of felling one of the virgin redwoods of California. This tree has been growing since 600 B.C., but will be cut down in less than an hour. Every year powerful private lumber interests are destroying more and more of these noblest of our native trees. Many redwood groves, to be sure, have been rescued by acts of state and national legislatures, but many others have been and are rapidly being destroyed.

Exercises. If you believe that the redwood forests of California represent a national asset of beauty which should be saved—and if you want to do your bit to help save them—write to the Save-the-Redwoods League, 219 California Hall, University of California, Berkeley, California. It will tell you about the grave dangers that threaten the virgin redwood forests of the Pacific coast and what you can do to help.

Are there evidences of wasteful tree-cutting in your community? What are the evidences?

The lumbering industry is not the only enemy of our forests. It is not even the greatest enemy. Fire has destroyed many more trees than has the ax. Millions of acres of timberland are burned over every year. Experts estimate that about 10 per cent of this destruction is caused by

Horace Bristol

The mighty redwoods can resist every enemy but man

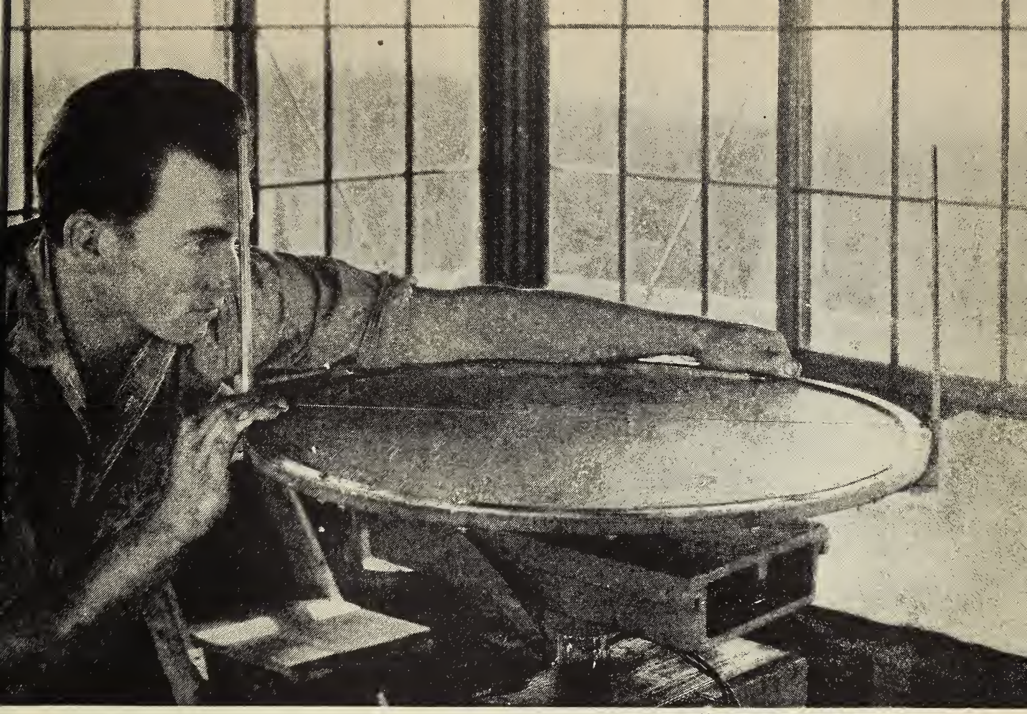
lightning, 90 per cent by carelessness. *The careless smoker and the careless camper are the greatest enemies our forests have.* To leave a campfire smoldering in the woods is as much a crime as to set fire deliberately to a building.

Exercise. Look up in the Boy Scout Handbook or in some other manual of woodcraft the proper way of using fire in the woods. Make a list of the cautions that should be taken, and report on them to your class.

Though man is the greatest enemy of the forests, storms, floods, and disease also take their toll. Of the so-called natural enemies of trees, disease is much the most deadly. The gypsy moth, the white-pine blister rust, the Dutch elm disease, and many other insects and diseased conditions attack our forests. They take a yearly toll of more than one hundred million dollars.

The United States Forest Service is the guardian of such forest lands as the national government has claimed in the interest of all the people. In the national parks and national forests green-suited "rangers" are efficiently guarding the trees from their enemies. The photograph on the opposite page shows a forest "lookout" in his perch on the top of a mountain. Hundreds of square miles of timbered land lie at his feet. When he sees a thread of smoke rising above the treetops, he telephones its position to a station below. Immediately "smoke-chasers" are sent to the danger spot. If the forest is not too dry and the wind too high, the fire is put out before it spreads very far.

Though the Forest Service is the greatest organization for forest conservation, it is not the only one. Many other government and private organizations are devoted to the task of saving our forests and of replacing the forests which



U. S. Forest Service

On many a mountain top "lookouts" guard our forests against fire

have been gutted by fire, greed, and disease. We should all try to help in this cause. People will always need wood, and trees will always have to be cut down. The only way to prevent such wood famine as has fallen on large parts of China (where many people have to pinch and scrape to afford enough wood for their coffins) is to make new trees grow where old ones have been felled.

Exercise. Look around your neighborhood and select a place where a tree might bring beauty, shade, fruit, or some other benefit. Then find a young tree and plant it there. No better form of conservation can be practiced.

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. Conservation is not a matter for the individual but rather for the state and national governments.

2. If everybody practiced small-scale conservation, large-scale conservation would be unnecessary.

3. When the white man came to America, he found that the red man had already begun to drive the bison from the plains and the passenger pigeon from the air.

4. Fishermen are the greatest enemies of fish.

5. Modern commercial methods of fishing take less toll from the resources of the waters than the more barbarous methods of the Indians.

6. The shad and salmon fisheries of the Atlantic coast have been saved through the use of fish ladders.

7. Pollution of water by sewage is no serious menace to water creatures because they have become adapted to live in poisonous surroundings.

8. Though we have driven the bison and the antelope from the plains, we have preserved our wild fowl by carefully guarding the swamps and marshes in which they breed.

9. The lumbering industry has been the greatest enemy of our forests.

10. Most forest fires are caused by lightning.

11. Only 62 per cent of every tree which is cut down for lumber is used.

Questions for Discussion

1. Are any natural resources being wasted in the region around your home? If so, discuss with your schoolmates the best means of applying conservation.

2. Do you think that certain wild animals are harmful and therefore should not be protected by law? If so, what animals? Be sure that you consider all the habits of an

animal before you judge it harmful. A bird, for example, may steal a few cherries or chickens from a farmer but pay for them by eating large quantities of insects or mice which are harmful to crops.

3. Fifty years ago about three fourths of our forested lands were owned by state and national governments. Now about four fifths are owned by private individuals and corporations. Under what ownership—government or private—do you think our forests are better conserved?

Things to Do

1. On an outline map of your state ink in all the regions where wild life is protected. Such regions are national and state forests, parks, monuments, game preserves, bird refuges, and large city parks. Government bulletins and perhaps the chambers of commerce of the large towns and cities of the state can supply the needed information.

2. The United States Bureau of Biological Survey, the National Parks Service, the Bureau of Fisheries, and the Forest Service, all with headquarters in Washington, D.C., are the great Federal bureaus for the conservation of wild life and forests. The National Association of Audubon Societies is a great private organization which has been active for years in fighting the slaughter of wild life. Write to any of these organizations for literature on the phases of conservation which are most important in your region.

3. The problem of reforestation is a new one for us but an old one for the nations of Europe. France, in particular, has met this problem well. Look up an account of reforestation in France, and prepare a report for your class.

4. Read *Rich Land, Poor Land*, by Stuart Chase, for an interesting and stirring account of how we have wasted our natural resources.

CHAPTER NINETEEN

How Can We Save Our Minerals and Soils?

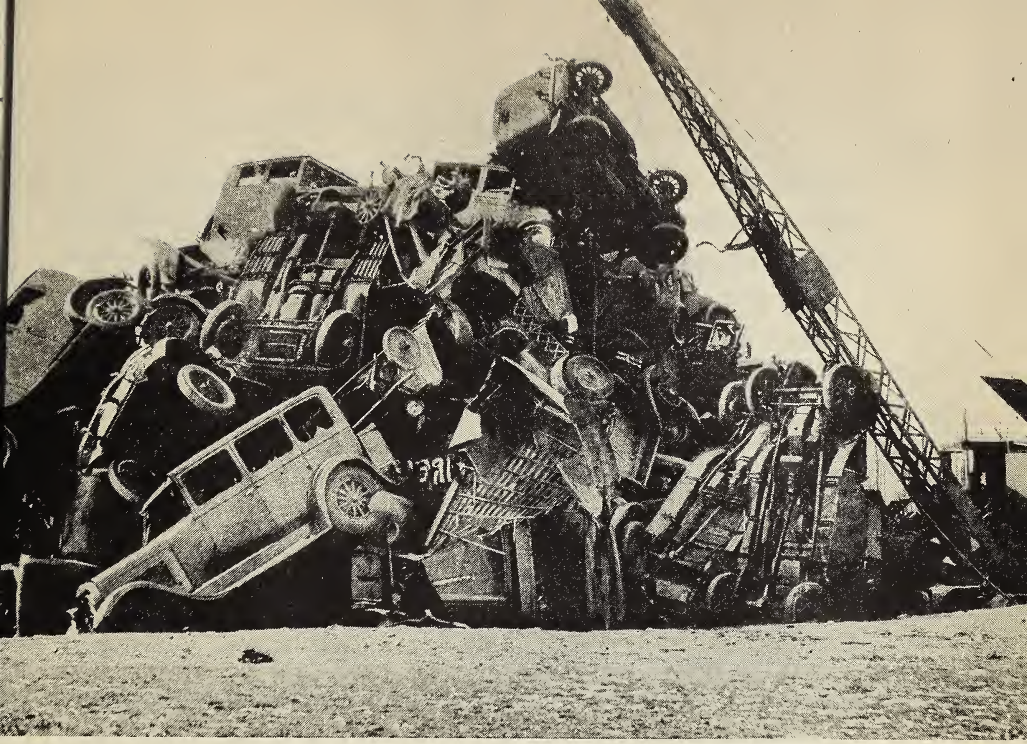
THE CONSERVATION OF METALS

The Problem of Saving Our Metals. We live in an age of machinery, and most machines are made of metal. Naturally we must conserve metals if our machine civilization is to continue. How much metal exists in the world and how can we best conserve the supply?

Iron, aluminum, copper, lead, zinc, chromium, and the many other metals on which modern civilization is based are taken from the rocks of the earth. The farmer who harvests a crop from a field knows that other crops will grow in the years to come. The miner takes ore from a mine and knows that the mine is just that much poorer. In mining there is only one crop; when that is harvested, the mine becomes worthless.

Not only this, but the minerals that contain useful metals make up a very small percentage of the earth's crust. Long ages were needed for the formation of valuable mineral deposits which can be exhausted in a few years. Not only are many rich reserves of the metal minerals being used up, but ever-increasing demand for metals hastens the day of complete exhaustion. Indeed, certain metals—tin, for example—once fairly common have already become rare.

Under such conditions, how is the conservation of metals possible? Obviously *the best way to conserve these valuable materials is to do away with waste in mining and using them.* Fortunately all the nations of the world now realize



International News

Much of the metal in this automobile "graveyard" will waste away in rust

the value of their metal minerals, and wasteful mining methods have rather generally been replaced with more economical ones. Mines are now developed so that a much larger percentage of metal can be taken from a given quantity of rock than was possible in the past. Old mines are being reworked to recover values that were overlooked before.

Exercise. What becomes of the worn-out machinery of your town or community? Visit the dump heaps with a camera. Do you find iron, copper, tin (coating on "tin" cans)? What other metals can you recognize?

Iron is the foundation of our machine civilization, and must be conserved if our civilization is to go on. Fortunately the iron reserves of the world are great, but that is

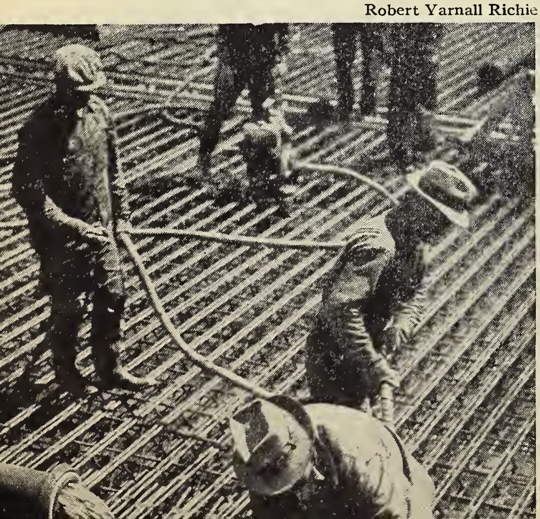
no reason why iron should be recklessly destroyed. The need of conservation is being met in many ways. Scientists have found ways of mixing iron with other metals to make a variety of *alloys* which are much more durable than iron alone. When you see the gleaming body of a modern streamlined train, you see iron in one of its strongest, hardest, and most rust-resisting forms.

Exercise. Metallurgy is the science that deals with the preparation of metals for use. Look up the alloys of iron in a modern textbook of metallurgy or in a modern encyclopedia. Make a report on three or four of these alloys, explaining how each one is made and what need it is designed to meet.

The Use of Low-Grade Ores. Any rock from which a metal can be extracted profitably is called an ore. Naturally miners have been most eager to dig out the ores that yield the greatest profit. Gold and silver are rare metals which have been selected as the standards of value in the civilized world. They have always been conserved very carefully for this reason. Their value, however, is purely artificial because—aside from their use as money—they play a very small part in modern civilization.

Iron alloys are the backbone of modern civilization

Robert Yarnall Richie



Iron, which is actually much more valuable than gold and silver because of the part it plays in modern life, is much less valuable in dollars and cents. Compared with most other metals, it is very common, and its low cost has been made possible

by the large reserves of rich iron ore which occur in many parts of the world. But these high-grade deposits, as they are called, are slowly being consumed. The time will come when they will be completely exhausted.

Exercise. Ask a hardware merchant how many pounds of iron come into your community every year. Maybe he can help you estimate how much old metal goes back to the mills to be built into new machinery and how much is wasted.

The mining of high-grade ores cannot extend beyond the time when all the known deposits of high-grade ores are mined out. Fortunately the high-grade iron and also the high-grade aluminum deposits of the world are so great that they will not be exhausted for many years. High-grade deposits of copper, lead, zinc, and tin, on the other hand, are being used up very rapidly. Copper, in particular, is finding new uses every year with the growth of the vast electrical industries. The high-grade reserves of this metal are rapidly disappearing.

How can we meet this problem of diminishing metals in a civilization which is based on metals? Fortunately there is an answer. Scattered widely through the rocks are vast deposits of low-grade ores which cannot be exhausted for a very long time. *One of the chief problems of metal conservation is the problem of learning how to use these low-grade ores.*

Scientists have already made great strides in this field of conservation. They have learned to extract metals at a profit from rocks which only a few decades ago could not have been mined except with great financial loss. With continued improvement in mining and metallurgical methods, as well as in the economical use of the products after they

leave the mines, smelters, and factories, our metal resources can be conserved almost indefinitely.

Exercise. Look up in an encyclopedia or in some book on minerals and mining the methods used in mining low-grade copper ores in Arizona. Make a brief report on your findings.

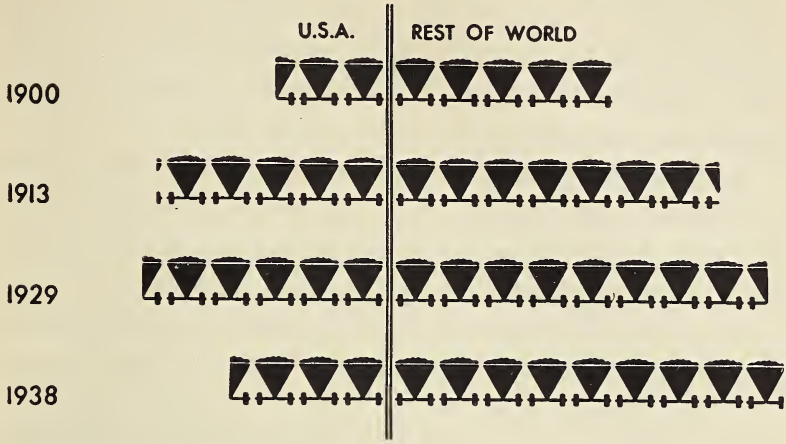
THE CONSERVATION OF FUELS

The Conservation of Coal. Metal is not enough to keep the Machine Age going. Fuel is needed to run the machinery. Coal is needed to turn the wheels of countless factories and farms, and of many electric-power plants and railroads. Petroleum is needed to run our automobiles, and in many cases to heat our houses and to move our ships and our railroads. Gas is used in millions of places for cooking, heating, and cooling.

Next to iron, coal is the most important mineral product in the world. Like all other mineral deposits, the coal deposits of the world were slow in forming and are definitely limited in extent. We are using up our valuable reserves of coal at the rate of one to two billion tons a year. If the use of this mineral should continue to increase as it has in the past, in less than two hundred years the entire supply of high-grade coal will have been burned up (see graph on the opposite page).

Though petroleum is challenging the leadership of coal in the industrial world, coal is still extremely important to civilized man. A world without coal would be very different from the world today. One of the most pressing problems in the entire field of conservation is the problem of extending the life of our coal reserves. Fortunately there are ways of doing this.

WORLD PRODUCTION OF COAL



Each symbol represents 100 million long tons

Tremendous quantities of coal are burned each year[1]

Coal-mining Is, and Always Has Been, Attended by Great Waste. Pillars and walls of coal are generally left standing in the mines to prevent the collapse of roofs, which would not only endanger the lives of the miners but also the houses on the land above the mines. Such pillars and walls of coal represent a great waste of valuable fuel. There is no doubt that in the future it will be necessary to use concrete pillars and thus save the many millions of tons of coal which are now being wasted.

Another source of waste lies in the transportation of coal from the mines to the factories, homes, and other places that use it. Coal is heavy, and many millions of tons are burned each year merely to supply the power for carrying other millions of tons from place to place. Experiments have proved that in many cases coal might better be burned

[1]Pictorial Statistics, Inc., from Casner & Peattie, *Exploring Geography*, Harcourt, Brace & Co.

at the mines and its energy sent by electricity to the places that need it. In many other cases it has proved profitable to burn coal in large central heating plants, and to pipe the heat to near-by buildings. Much expense can thus be saved and much coal conserved for our descendants.

Perhaps the greatest of all wasters of coal was the old-fashioned steam engine. Only about 15 per cent of the energy of coal was converted into power by that machine; some 85 per cent was lost to the air in the form of heat. Of the 15 per cent saved, much was wasted in old-fashioned power plants that used the energy of coal to produce light. It is estimated that in the early days of electric lights an ordinary bulb used only one five-hundredth of the energy of the coal which was burned to produce the light.

Fortunately modern machinery for using coal is much less wasteful of energy. In many industries much less coal is now being used than formerly to produce the same amount of power. Through the invention of more efficient locomotives, railroads have cut down their coal consump-

This will give you an idea of the importance of coal in the modern world

Ewing Galloway

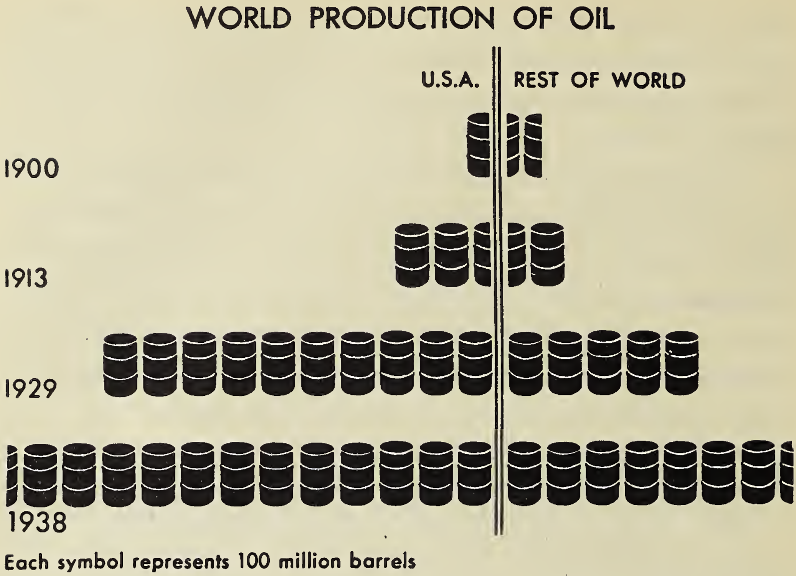
tion to about two thirds of what it once was. Modern electric-power plants require only about one sixth as much coal to generate a given amount of electricity as was required in 1902.

Even though every known kind of conservation is used on our dwindling coal reserves, the end of coal is in sight. One thousand—at most, two thousand—years and all the known low-grade and high-grade deposits of coal are likely to be exhausted. What will the world do then? Before we attempt to answer this question, let us see what is happening to petroleum, the other great modern fuel.

Exercise. List half a dozen coal-using industrial plants near your home. If possible, visit one of these plants and see if you can learn (1) how much the power which runs the plant costs; (2) where there is waste in the use of the coal or the energy taken from the coal.

The Conservation of Petroleum. The petroleum, or oil, industry, though much younger than the coal industry, has had a similar history. In half a century petroleum has risen from a curiosity to one of the most eagerly sought and most widely needed minerals on earth. Over three hundred products of petroleum are now being sold, and each year many new ones are developed. The graph on page 504 shows the increase in the production of oil since 1900.

The chief use of petroleum, however, is for fuel. Occurring for the most part as a liquid in underground pools which are widely scattered over the surface of the earth, petroleum is easily obtained by drilling. On page 505 is a picture of a modern oil-drilling rig. The same page contains a picture of a pipe line by means of which the crude petroleum is carried cheaply from the well to the refinery, where it is made into gasoline and other products.

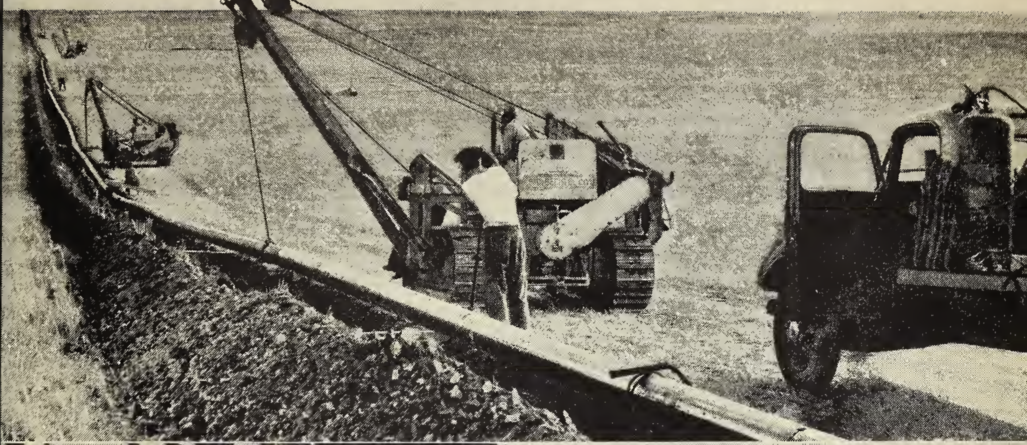


Oil changed almost overnight from a curiosity to a world-wide necessity[1]

The early days of the petroleum industry were marked by enormous waste. On the opposite page is a photograph of a "gusher," an oil well which is out of control because of faulty methods of drilling. Gushers are rare today in scientifically operated oil fields, but they have wasted untold millions of barrels of petroleum in the past.

As long ago as 1920 the head of the United States Geological Survey estimated that about two fifths of the oil reserves of the United States were already exhausted. At the present time the world is consuming more than two billion barrels of petroleum every year. Nobody knows exactly how long the reserves can last at this rate of use, but anybody can see that they cannot last very long. A hun-

[1]Pictorial Statistics, Inc., from Casner & Peattie, *Exploring Geography*, Harcourt, Brace & Co.



Galloway

Meyers

The pipe line (top) will carry oil from the wells to the refinery. The men (lower left) are drilling an oil well. Notice the lengths of pipe that will be placed in the hole as it deepens. The "gusher" (lower right) is the result of bad drilling

dred or two hundred years may well see the end of oil What will the world do then?

Exercise. The oldest commercial oil fields in the world are in Pennsylvania. Look up the record of petroleum production in Pennsylvania. What does this show as to the probable future of petroleum production in California, which contains some of the youngest oil fields in the United States?

The Future Source of Power. In spite of all modern attempts to conserve our valuable deposits of coal and oil, about one ton of coal is wasted for every three tons that are mined; about one barrel of oil is left in the ground for every barrelful that is pumped out. But even though this waste should be greatly reduced in the future, *the day must come when there will be no more coal and oil.* The people of that future day will have to turn to such nonmineral fuels as alcohol (which can be made on a large scale from corn), and to wind, running water, and possibly the direct rays of the sun.

Great steps have already been taken to increase the water power of the United States. We have all read about Boulder Dam, Grand Coulee Dam, the dams of the Tennessee Valley, and other modern power and irrigation projects. These will undoubtedly help fill the ever-growing need for water, heat, and light. Experts, however, believe that *even though all the water power in the world were to be harnessed, it would not be able to supply all the power needed by modern industries.*

Nobody knows exactly where additional power will be found. Possibly solar steam engines with mirrors to concentrate the rays of the sun will turn the trick. Man's search for new sources of energy is as old as man himself. Here-

tofore he has found all the energy he has needed, and he will probably always be able to do so. At present, however, coal and petroleum are much the cheapest and most practical sources of energy for industrial purposes. We should bend every effort to make them last as long as possible.

THE CONSERVATION OF SOILS

Our Vanishing Grasslands. If you turn back to the map on page 487, you will see that much of the central portion of the United States supported no forests when the white men took this region from the Indians. The Dakotas, Iowa, Kansas, Nebraska, and large areas in neighboring states are, and always have been, natural homelands for grass. The white colonists of these so-called prairie areas destroyed the grass just as other colonists destroyed the trees—and with equally disastrous results.

They did so in two ways. By *plowing* for farms, they cleared large areas of grass just as other settlers farther east cleared large areas of trees. By allowing too many cattle and sheep to graze on the pasture lands (*overgrazing*), they allowed the grasses to be cropped and trampled to death. The photograph at the top of page 508 shows a grassland that has not been abused. The photograph at the bottom shows what happens to a grassland when it is abused and one of the commonest causes of the abuse.

Exercises. On an outline map of North America mark all the natural grasslands. Get the necessary information from a textbook of geography, or write to the Department of Agriculture.

Do you live in a region that was covered with grass or with forest before white men settled this country? How do

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A properly grazed range is green and thick with grass

An overgrazed range is brown and dusty

U. S. D. A., Soil Conservation Service

you know? Are there evidences in your community of overplowing or overgrazing? What are the evidences?

Overplowing and overgrazing, together with deforestation, have done a tremendous amount of damage to our country and its people, as we shall see.

Normal and Abnormal Erosion. In Chapter Thirteen you learned that rain, running water, wind, and other natural forces are forever tearing down the surface of the land. You learned that this process is called erosion, and that it is a perfectly normal condition. Soil is normally being carried *slowly* from higher to lower places.

The destruction of trees and grasses on the steep slopes around the headwaters of streams tends to speed up the process of erosion. Rain falling on such slopes has little vegetation to retard its flow to lower levels. It consequently moves downward with greater speed and force than it normally would. Without their normal protective covering of trees and grasses, the slopes are rapidly worn away. Thus an abnormal condition of *rapid* erosion is set up.

Under normal conditions new soil is made from the weathering of rocks as rapidly as old soil is carried away by erosion. Under abnormal conditions old soil is carried away more rapidly than new soil can be made to take its place. The result is that wherever abnormally rapid erosion goes on, the fertile topsoils disappear and farm lands are destroyed. So widespread is this condition in our country today that it has become one of our most serious national problems.

The Chain of Disaster. We all know that we get burned if we put our fingers in a flame. When we were very young, however, we probably did not know this. We probably had

U. S. D. A., Soil Conservation Service

Burned and cut-over forest lands (left) breed streams that erode their banks at an abnormally rapid rate (right)

to make the experiment before we learned that fire plus fingers equals getting burned. In the same way, as a nation we now know that the destruction of forests and grasslands brings rapid erosion with its host of resulting disasters. When we were younger as a nation, however, we did not know this sufficiently well to prevent it.

In many places in our land today we can follow the chain of disaster which starts with what once seemed a harmless act.

LINK *1 is deforestation.* The photograph at the left above shows a hillside near the source of a stream which has been cut and burned clean of its trees. Water falling on this hill meets little resistance. It flows down the hill, picking up soil as it goes and swelling the stream below.

LINK *2 is the swollen stream* which deepens and widens

Little rills flowing over bare slopes (left) make gullies which in time bring ruin to the land (right)

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The cutting of forests and the plowing of grasslands bring dust storms (left) which in turn bring death to farm lands (right)

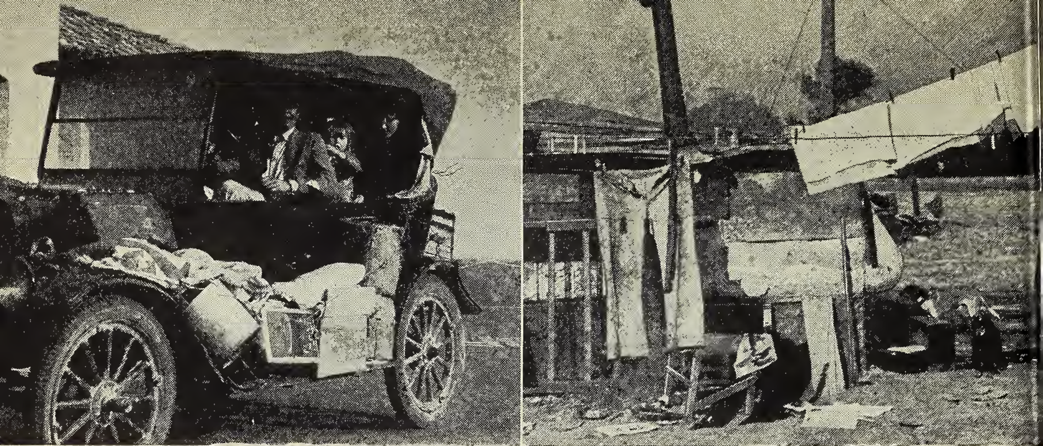
its channel at an abnormal rate—and at the expense of the farms that border it. (See top right picture on opposite page.)

LINKS *3 and 4 are overplowing and overgrazing* on the lands farther down the stream. The illustrations at the bottom of the opposite page show how little rills are started on slopes which have lost their protective covering of grass. In the next stage the little rills grow into ugly gashes (gullies). Finally the gullies join in a network over the land, completely destroying its value.

LINK *5 is the horrible dust storm.* Hundreds of thousands of acres without grass or trees to hold the soil in place are easy victims of the wind, particularly in the drier portions of the Western plains. The swirling dust storm shown at the left above is the result. When the wind stops blowing, it drops its load of sand and soil without any refer-

Flooded cities (left) and abandoned farms (right) are caused by land abuse

Pictures, Inc. U. S. D. A., Soil Conservation Service

Lange for Resettlement Administration — Horace Bristol

Erosion made these people homeless and hungry

ence to our convenience. It smothers fields of growing things. It blocks roads. It buries farm buildings. It turns the land into a desert. (See top right picture on page 511.)

LINK *6 is the equally horrible flood.* With little vegetation to hold back the melting snows and rains of spring, the upper reaches of rivers pour down more water than the channels of the lower reaches can hold. The rivers widely overflow their banks, and disaster spreads with the water. (See lower left picture on page 511.)

LINK *7 is the end of the chain: poverty and migration.* The lower right picture on page 511 shows what was once the home of a prosperous farmer and his family. Erosion destroyed the surrounding fields, and the family moved out. Somewhere they are trying to begin life all over again. The photographs above show emigrants from the "Dust Bowl" of the Central States, looking for new land on the Pacific coast. Unfortunately there is not enough new agricultural land to take care of all such unfortunate people.

Breaking the Chain. The chain of disaster which we have just followed does not make a pleasant sight. Though in many places the chain is not linked up exactly as we have described it, the general results are the same. *Vast areas*

in America have lost and are losing their valuable topsoils, with hardship and poverty the result. Fortunately there are remedies for this unhappy situation, remedies which are fairly obvious.

Remedy 1. *The destruction of forests* around the headwaters of streams *must be stopped.* Lumbering activities must be regulated by scientists who know what trees it is most profitable to fell. It must be regulated by state and national governments that have the interest of all the people at heart. Where deforestation has occurred, new trees must be planted, and planted at once. This work has already begun, as the illustration below shows.

Remedy 2. *Grass should be allowed to return* to the drier regions of the Western Plains and thereby heal their wounds. These regions should never have been plowed and extensively grazed in the first place. Whatever farming is done there in the future should be strictly regulated with reference to possible disastrous erosion (see photograph on page 514).

This tree nursery is helping to solve the grave problem of deforestation

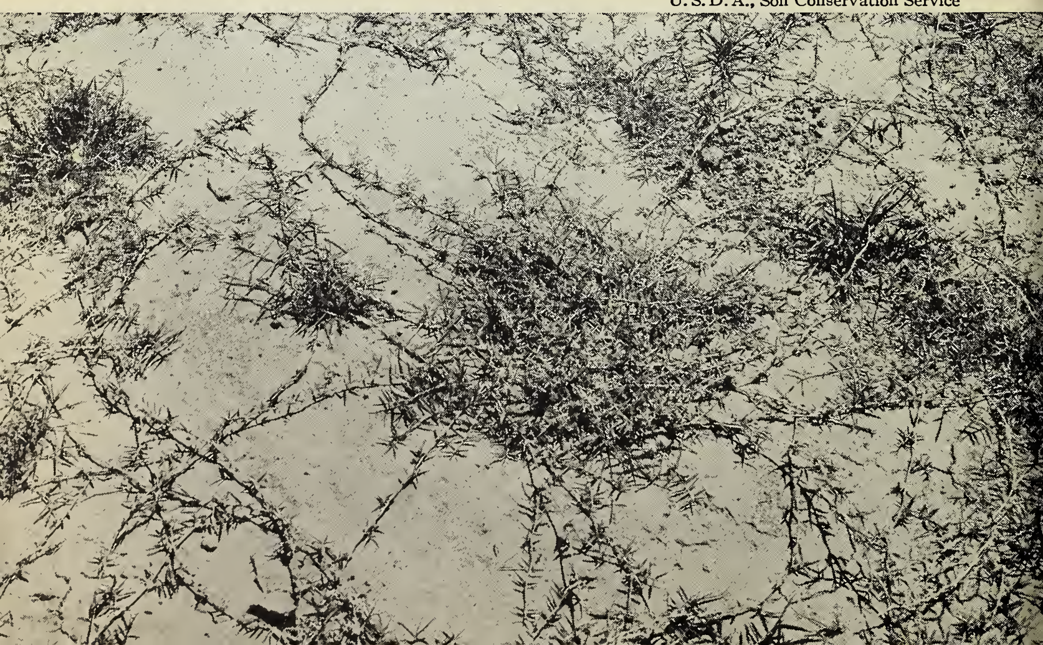
U. S. Forest Service

REMEDY 3. *Contour plowing should be practiced* wherever farm lands have any slope over which water can run and erode. *A contour is a horizontal line on the surface of a slope.* Instead of the usual method of plowing, which goes up hill and down dale to make the usual square pattern of a tilled field, contour plowing curves around the slopes, as shown on the opposite page. In this way each plowed furrow and planted row acts as a little dam to slow down the water that runs over the field. In the ordinary "up-and-down" plowing, the rows and furrows make gutters, which help and hasten erosion.

REMEDY 4. *Strip cropping should be practiced* generally on sloping ground. This consists in alternating strips of close-growing crops (such as wheat or clover) with strips of more open-growing crops (such as corn and potatoes). The close-growing plants, with their matting of roots, act as dams to check the runoff of soil from the less-well-protected strips, and also as blotters to draw the water into the ground (see photograph on the opposite page).

These grass plants are helping to heal the wounds of an overgrazed prairie

U. S. D. A., Soil Conservation Service



U. S. D. A., Soil Conservation Service

Contour plowing and strip cropping help slow down the water that flows over sloping farm lands

REMEDY 5. *Terracing may effectively be used* in connection with contour plowing and strip cropping. It consists in building terraces a few feet in height along the contour lines of sloping fields, as shown on page 516. Terraces of this sort slow down running water on plowed fields and reduce erosion.

REMEDY 6. *Check dams should be built.* They are small structures built across gullies and on the upper reaches of streams to slow down running water. They can be made of logs, saplings, stones, or wire netting. They are useful not only as devices for the control of erosion and flood but also as watering troughs and irrigation reservoirs in dry regions.

Exercise. The schoolboys pictured on page 517 are building a check dam to stop the gullies which have already begun to grow. See if you can find some place in your

Civilian Conservation Corps

Terraces help to reduce erosion of plowed fields

locality where gullies are beginning to cut up a farmer's field. Try to arrange with the farmer to help him build a check dam.

REMEDY 7. Finally *irrigation projects* are needed for opening new farm lands to the millions of people who have been made homeless by soil erosion. In this department, conservation is leaping ahead very rapidly. The map on page 518 shows the region of Grand Coulee Dam, the largest man-made structure on earth. It will open thousands of square miles of now worthless land to agriculture.

Exercise. The Soil Conservation Service has many erosion-control demonstration areas in operation in the United States. Write to this organization (which is part of the Department of Agriculture, Washington, D. C.) or to your state college, and find out where the demonstration nearest to your home is located. Visit it and make a report for your class.

Change without End. With this study of conservation we come to the end of this book. We have seen that many of the changes of a changing world are beyond our control; that to these we must adjust ourselves as best we may. We have seen that many other changes are brought about by our own activities; that these we must control intelligently and unselfishly. In either case our lives will be lived in an ever-changing world. We have come to the end of this book, but we shall never come to the end of the subject with which it deals.

These children are building a check dam across a gully to slow down the water that flows down the hill when it rains. Is there a gully in your neighborhood which you can keep from growing by building a similar dam?

Life Magazine

The Grand Coulee Dam and irrigation project is one of the greatest undertakings of modern times

Correct These Statements

The following statements are partly or wholly false. Correct them and discuss your corrections.

1. There are enough high-grade iron ores in the world to last practically forever; so conservation of iron is not necessary.

2. The reason why we must conserve many metals is that the high-grade deposits are fast being exhausted and the low-grade deposits are too poor to be worked.

3. Though coal-mining has been attended by much waste in the past, it is now being done economically.

4. Thanks to the efficiency of the steam engine, our fuels can be conserved for a long time.

5. Valuable deposits of petroleum should still exist a thousand years from now if we practice careful conservation.

6. If all the coal and oil in the world should disappear tomorrow, water power could be developed to supply all the energy needed by modern industry.

7. It is natural that soil should be gradually stripped from the lands until there is none left.

8. Dust storms cannot be prevented because they are caused by wind blowing over regions which are too dry to support any grasses.

9. Floods cannot be prevented because the melting snows and rains of spring cannot be stopped.

10. "Contour plowing" and "strip cropping" are different terms for the same thing.

Questions for Discussion

1. Why are coal and oil deposits a valuable asset to a nation? Discuss this subject with reference to both peace and war.

2. Can you think of any fields which we have not studied in this unit where large-scale conservation is necessary?

Things to Do

1. Iron, copper, aluminum, coal, and petroleum are the five most important minerals in modern industry. On outline maps of North America mark where deposits of each of these minerals occur. Get your information from a geography or a mineralogy textbook or from an encyclopedia. How do our mineral resources compare with those of Great Britain? Germany? Russia?

2. Make a survey of farming methods in the neighborhood of your home. Locate all farm lands which are being harmed or which may be harmed by rapid soil erosion, and suggest all possible remedies for each case. This might well be a class project, with students working in pairs in different localities.

3. Read *Behold Our Land*, by Russell Lord, an up-to-date and interesting discussion of the menace of soil erosion.

4. Write to the Soil Conservation Service, Washington, D. C., for a list of their pamphlets. Many of these pamphlets are interestingly written and well illustrated, and are free to schools as long as the supply lasts.

Readings in Science

Andrews, Roy C. *Exploring with Andrews.* G. P. Putnam's Sons, New York, 1938.

A book for younger readers, describing adventures in the life of this famous explorer.

Baer, Marian. *Pandora's Box.* Farrar & Rinehart, Inc., New York, 1939.

A story of conservation of our natural resources.

Baker, R. H. *Introducing the Constellations.* Viking Press, Inc., New York, 1937.

Here is a good book on the history of astronomy and the Greek myths, as well as an account of present-day improvements in telescopes.

Botley, C. M. *The Air and Its Mysteries.* D. Appleton-Century Company, Inc., New York, 1940.

Facts about the air and the weather and their effects on us, by a noted English scientist. There are chapters on aviation and animals with wings.

Bradley, John H., Jr. *Autobiography of Earth.* Coward-McCann, Inc., New York, 1935.

A story of the earth's beginnings and of rocks, volcanoes, rivers, and minerals today. Man is the central figure.

Bradley, John H., Jr. *Parade of the Living.* Coward-McCann, Inc., New York, 1930.

The author traces vividly the procession of living forms that have occurred on the earth.

Brewster, Edward T. *This Puzzling Planet.* Bobbs-Merrill Company, Indianapolis, 1928.

The story of the earth's geology and early life.

Brooks, Charles F. *Why the Weather?* Harcourt, Brace and Company, New York, 1935.

A revised edition of a popular book answering a great many questions about the weather.

BUCK, FRANK. *On Jungle Trails.* World Book Company, Yonkers-on-Hudson, 1936.

A description of jungle animals in their natural haunts.

BYRD, RICHARD E. *Discovery.* G. P. Putnam's Sons, New York, 1935.

The story of the second Byrd antarctic expedition.

BYRD, RICHARD E. *Exploring with Byrd.* G. P. Putnam's Sons, New York, 1937.

Exciting adventures in extending the field of scientific knowledge, told in Byrd's always excellent manner. Easier reading than the previous book.

CASTERET, NORBERT. *Ten Years under the Earth.* Keystone Publishing Company, Philadelphia, 1938.

Explorations of caves and caverns, and prehistoric remains.

CHAPMAN, FRANK M. *Life in an Air Castle.* D. Appleton-Century Company, Inc., New York, 1938.

Observations of wild life in a protected naturalist's paradise in Panama.

CHASE, STUART. *Rich Land, Poor Land.* McGraw-Hill Book Company, Inc., New York, 1936.

A story of the natural resources of the United States, their use and misuse.

CROWDER, WILLIAM. *Dwellers of the Sea and Shore.* The Macmillan Company, New York, 1938.

Life along the seashore.

DITMARS, RAYMOND L. *The Book of Prehistoric Animals.* J. B. Lippincott Company, Philadelphia, 1938.

A story about extinct reptiles and mammal-like reptiles, birds, and mammals of long ago. Good drawings.

DITMARS, RAYMOND L. *The Fight to Live.* Frederick A. Stokes Company, New York, 1938.

Defensive mechanisms of birds, reptiles, and mammals used for protection against enemies, in the search for food and in defense of their young.

DITMARS, RAYMOND L., and CARTER, H. *The Book of Living Reptiles.* J. B. Lippincott Company, Philadelphia, 1938.

All about crocodiles, alligators, turtles, and lizards, and where these fascinating animals are found.

Fenton, Carroll L. *Along the Hill.* Reynal & Hitchcock, Inc., New York, 1935.

A small guidebook about rocks and fossils.

Fenton, Carroll L. *Our Amazing Earth.* Doubleday, Doran & Company, Inc., New York, 1938.

A description of earth changes and of the living things that have existed under these changing conditions.

Fisher, Clyde. *Exploring the Heavens.* Thomas Y. Crowell Company, New York, 1938.

A book based on the lectures on astronomy by the Director of the Hayden Planetarium.

Fisk, Dorothy M. *Exploring the Upper Atmosphere.* D. Appleton-Century Company, Inc., New York, 1935.

A book about the stratosphere and the properties of the upper air.

Gaer, Joseph. *Men and Trees.* Harcourt, Brace and Company, New York, 1939.

Excellent illustrations in a book telling the story of tree conservation by the United States Forest Service, with emphasis on its relation to soil and water conservation.

Glover, Katherine. *America Begins Again.* McGraw-Hill Book Company, Inc., New York, 1939.

The story of how America has at last begun to conserve its natural resources.

Hegner, Robert W. *Parade of the Animal Kingdom.* The Macmillan Company, New York, 1935.

A large and informative book about animals, from the amoeba to the gorilla. Excellent illustrations.

House, Homer D. *Wild Flowers.* The Macmillan Company, New York, 1934.

Color plates, in natural size, of the common wild flowers of New York and other northeastern states.

Huntington, Ellsworth. *The Human Habitat.* D. Van Nostrand Company, Inc., New York. 1927.

A book discussing the effect of climatic and geographic factors on man's economic, cultural, and social welfare.

Ilin, Max. *Turning Night into Day.* J. B. Lippincott Company, Philadelphia, 1936.

The story of lighting, by a Russian author, written for use in Russian schools.

Innes, William T. *Exotic Aquarium Fishes.* Innes Publishing Co. Philadelphia, 1935.

Most unusual colored illustrations and descriptions of tropical fish, together with suggestions for care of these fish. The author is a leading authority in the field.

Jaeger, Edmund C. *Desert Wild Flowers.* Stanford University Press, 1940.

A reference book describing more than seven hundred fifty plants of our southwestern deserts, with drawings.

Kallet, Arthur, and Schlink, F. J. *100,000,000 Guinea Pigs.* Vanguard Press, Inc., New York, 1932.

There are dangers in some commonly used foods, drugs, and cosmetics. Others are entirely useless.

Knight, Charles R. *Before the Dawn of History.* McGraw-Hill Book Company, Inc., New York, 1935.

The illustrations are reproductions of Knight's paintings. Brief stories accompany each picture.

Lamb, Frank H. *Book of the Broadleaf Trees.* W. W. Norton & Company, Inc., New York, 1939.

How the broad-leaved trees of the temperate zone contribute to economic and social welfare.

Lindbergh, Anne Morrow. *Listen! The Wind.* Harcourt, Brace and Company, New York, 1938.

Even more interesting perhaps than *North to the Orient*, this book tells the author's experiences in air travel about the world.

Longstreth, T. M. *Reading the Weather.* The Macmillan Company, New York, 1938.

Nontechnical discussion of the more common weather facts.

Loomis, F. B. *Field Book of Common Rocks and Minerals.* G. P. Putnam's Sons, New York, 1923.

A handbook for the identification of rocks and minerals, with good illustrations and careful descriptions.

LORENTZ, PARE. *The River.* Stackpole Sons, New York, 1938

A description, with many pictures, of the effects of rivers on human living. The story is the script of the United States documentary film of the same title.

LUDWIG, EMIL. *The Nile.* Viking Press, Inc., New York, 1937.

The life story of a river from its source on the equator to its delta on the Mediterranean, showing how the river affects the plants and animals along its course.

LUTZ, F. *Field Book of Insects.* G. P. Putnam's Sons, New York, 1921.

The book you need if you have found an insect that you cannot identify.

LYMAN, L. D., and ALLEN, C. B. *Wonder Book of the Air.* The John C. Winston Company, Philadelphia, 1938.

A Pulitzer-prize book telling what you want to know about aviation.

MCADIE, ALEXANDER. *Fog.* The Macmillan Company, New York, 1938.

A brief summary of what is known about fog and certain other weather phenomena.

MCADIE, ALEXANDER. *Man and Weather.* Harvard University Press, 1940.

Not easy reading for high-school students, but all the information is here if you are interested.

MCCLINTOCK, THEODORE. *The Underwater Zoo.* Vanguard Press, Inc., New York, 1938.

A day-by-day journal of adventures with fresh-water insect life.

MASON, GREGORY. *Columbus Came Late.* D. Appleton-Century Company, Inc., New York, 1931.

An account of ancient American civilizations—Maya, Toltec, Aztec —in Mexico. There are descriptions of Indian food plants, and of the progress of these peoples in mathematics and astronomy.

MILLS, CLARENCE A. *Living with the Weather.* Caxton Press, New York, 1935.

How weather affects us, and what we can do about it.

MORGAN, ALFRED. *Things a Boy Can Do with Electricity.* Charles Scribner's Sons, New York, 1938.

A book to acquaint boys and girls with the principles of electricity.

MORGAN, ANN H. *Field Book of Animals in Winter.* G. P. Putnam's Sons, New York, 1936.

Descriptions of the adaptations made by animals of the temperate zone to seasonal change.

MUENSCHER, WALTER C. *Weeds.* The Macmillan Company, New York, 1935.

A book for reference, with descriptions and a botanical key, so that you may know weeds and what to do about them. Many of them you may identify from the pictures.

OLCOTT, W. T. *A Field Book of the Stars.* G. P. Putnam's Sons, New York, 1936.

Another in this outstanding series of guide and reference books.

PARKINS, A. E., and WHITAKER, J. R. *Our Natural Resources and Their Conservation.* John Wiley & Sons, Inc., New York, 1936.

A detailed authoritative study of our natural resources, for adult use.

PATCH, EDITH M. *Holiday Hill.* The Macmillan Company, New York, 1935.

A simple but accurate little book with much information about rocks and soils.

PEARSON, T. GILBERT. *Birds of America.* The Garden City Publishing Company, Inc., New York, 1936.

Many pictures, some in color, with descriptions of all the common birds of the United States.

PEATTIE, DONALD C. *Green Laurels.* Simon & Schuster, Inc., New York, 1936.

Story of the discovery of the living world, through the biographies of the men who have led in the discovery.

PICKWELL, GAYLE. *Deserts.* McGraw-Hill Book Company, Inc., New York, 1938.

Vivid descriptions of the plants and animals that live in deserts and their adaptations to a desert environment.

REED, W. MAXWELL. *And That's Why.* Harcourt, Brace and Company, New York, 1935.

Simple explanations of such facts as why the ocean is salty, where to find petroleum, why mists hang over valleys in the evening, and so on.

REED, W. MAXWELL. *The Earth for Sam.* Harcourt, Brace and Company, New York, 1930.

Some simple principles of geography and geology told by Mr. Reed for his young nephew.

REED, W. MAXWELL. *The Stars for Sam.* Harcourt, Brace and Company, New York, 1932.

A book about the stars, in the same series as the previous book.

REED, W. MAXWELL, and BRONSON, WILFRID S. *The Sea for Sam.* Harcourt, Brace and Company, New York, 1935.

Another book for Sam. This one tells about the life of the sea and seashore.

REED, W. MAXWELL, and LUCAS, JANNETTE M. *Animals on the March.* Harcourt, Brace and Company, New York, 1937.

Stories of the development of the horse, cat, dog, and other common animals from prehistoric ages to the present.

ROBINSON, W. W. *Beasts of the Tar Pits.* The Macmillan Company, New York, 1935.

A story of the prehistoric mammals that perished in the asphalt beds of California.

ROSS, M. I. *Back of Time.* Harper & Brothers, New York, 1937.

Describing a scientific expedition in search of information about plants and animals in prehistoric deposits.

SEARS, PAUL B. *Deserts on the March.* University of Oklahoma Press, 1935.

When good soil becomes desert because of man's ill-treatment of it, the history of a country may become the history of a desert on the march.

SHANNON, HOWARD J. *The Book of the Seashore.* Doubleday, Doran & Company, Inc., New York, 1935.

"Where life goes on between the tides."

SHAW, NAPIER. *The Drama of Weather.* The Macmillan Company, New York, 1933.

The ever-changing scenes in the sky present a drama unsurpassed.

SMITH, B. W. *The World under the Sea.* D. Appleton-Century Company, Inc., New York, 1940.

The sea and the creatures that dwell therein, described by a British author.

SMOLKA, H. P. *40,000 Against the Arctic.* William Morrow & Company, Inc., New York, 1937.

The whole exciting story of Russia's new settlements within the arctic circle.

STARRETT, PAUL. *Changing the Skyline.* McGraw-Hill Book Company, Inc., New York, 1938.

A biography of the Starrett brothers in terms of the construction of such skyscrapers as the Empire State Building.

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Science Words

KEY TO THE SOUNDS

ă *as in* at	ẽ *as in* her	oi *as in* oil
ā *as in* ate	ẹ *as in* vowel	o͝o *as in* foot
â *as in* care	ĭ *as in* bit	o͞o *as in* food
ȧ *as in* ask	ī *as in* bite	ŭ *as in* us
ä *as in* arm	ŏ *as in* got	ū *as in* use
a̤ *as in* sofa	ō *as in* go	ṳ *as in* circus
ĕ *as in* bet	ô *as in* horse	tū *as in* nature
ē *as in* be	ọ *as in* connect	ŋ *as in* ink

acid (ăs′ĭd). A compound which has a sour taste when dissolved in water. All acids contain hydrogen (p. 338)[1]

adaptation (ăd ăp tā′shṳn). Change of the structure or behavior of a plant or animal or its parts. In this way it becomes better fitted for living in its environment (p. 192)

agar (ä′gär). Sometimes called agar-agar. A substance similar to gelatin (p. 319)

air bladder. A sac containing air. Air bladders are present in most fish and in some plants and animals (p. 294)

air pressure. The weight of air pressing on a surface. At sea level the pressure of the air is about 15 pounds per square inch; at higher altitudes, it is less (p. 97)

air sac. A small baglike part of the lungs containing air. Blood circulates around the air sacs, and oxygen passes through their walls into the blood (p. 437)

albatross (ăl′ba̤ trŏs). The largest of the sea birds (p. 291)

Allosaurus (ăl ō sô′rṳs). A flesh-eating dinosaur (p. 403)

alloy (ă loi′). A metal composed of two or more substances (p. 498)

American Medical Association. A profẹssional organization of American physicians, with headquarters in Chicago (p. 329)

amino (ă mē′nō) *acids.* Complex acids from which proteins are formed. Amino acids always contain nitrogen (p. 428)

amphibian (ăm fĭb′ĭ ăn). A kind of animal which usually passes the

[1]References are to pages in the text where the words first occurred.

first part of its life in the water and later lives mainly on land. Frogs, which as tadpoles live in water, are amphibians (p. 225)

Amundsen (ä'mŭn sĕn) *Roald* (1872–1928). A Norwegian explorer. He discovered the south pole in December, 1911 (p. 302)

analyze (ăn'ạ līz). To determine what anything is made of. Even light can be analyzed (p. 52)

aneroid (ăn'ẽr oid) *barometer*. A barometer in which the air pressure on an elastic metal box causes a pointer to move (p. 124)

Anopheles (ạ nŏf'ẹ lēz). The kind of mosquito which may transmit malaria to man (p. 232)

Antares (ăn târ'ēz). A very large, reddish star, 300 light-years away (p. 26)

anticyclone (ăn'tĭ sī'klōn). A condition of the atmosphere in which winds rotate about a center of high air pressure. The winds whirl outward and in a clockwise direction (p. 136)

antitoxin (ăn tĭ tŏk'sĭn). A substance formed in a living thing which will overcome the effects of a toxin (p. 317)

anus (ā'nụs). The end of the digestive system, through which solid waste leaves the body (p. 431)

aorta (ā ôr'tạ). The large artery which carries blood from the left side of the heart to the other arteries, which distribute it through the body (p. 436)

Archeozoic (är kē ō zō'ĭk) *era*. The earliest of the five great eras into which geologists divide the earth's history (p. 399)

arctic tern (ärk'tĭk tẽrn). A sea bird, smaller and slimmer than a gull, which each year migrates from the arctic to the antarctic regions and returns to the arctic (p. 240)

Arcturus (ärk tū'rụs). A large, bright star about 40 light-years away (p. 12)

Aristarchus (ăr ĭs tär'kụs). An ancient Greek thinker who believed that the earth revolved around the sun. This belief was considered irreverent by other men of his time (p. 33)

artery (är'tẹr ĭ). Any of the tubes which carry blood away from the heart (p. 436)

astronomy (ăs trŏn'ō mĭ). The study of the stars and other bodies in the heavens (p. 16)

atmosphere (ăt'mŏs fẽr). The gases surrounding the earth or those around other planets (p. 39)

axis (ăk'sĭs). A straight line upon which a body turns (p. 17)

bacteria (băk tē'rĭ ạ) [singular *bacterium* (băk tē'rĭ ụm)]. Plants so

small that they can be seen only through a microscope. Many bacteria cause diseases, but many others are very useful to man (p. 316)

Bantu (băn′tōō). A member of a large group of tribes living in equatorial and southern Africa (p. 329)

barnacle (bär′na̤ k'l). A small sea animal which can be found in groups attached to rocks, floating logs, and ships' bottoms (p. 280)

barograph (băr′ō gråf). A barometer which automatically records air pressures (p. 125)

barometer (ba̤ rŏm′ē tẽr). An instrument used to measure air pressure (p. 116)

basalt (ba̤ sôlt′). A dark-colored, fine-grained rock which was formed by heat (p. 378)

Bedouin (bĕd′o͝o ĭn). Wandering tribes of desert Arabs (p. 329)

Beebe, William (1877–). American scientist especially interested in tropical research and in studying life in the ocean (p. 293)

bell jar. A kind of glass container closed at the top and open at the bottom (p. 150)

belt of calms. An irregular section of the torrid zone where the air movements are mostly upward (p. 109)

Betelgeuse (bē′t'l jōōz). A large red star, probably about 250 light-years away from us (p. 26)

Big Dipper. The most conspicuous constellation in the northern sky. It is a part of the Great Bear, or Ursa Major (p. 12)

bile (bīl). The greenish-yellow liquid made in the liver. It is necessary for digestion (p. 434)

blister rust. A disease of pine trees (p. 492)

boulder (bōl′dẽr). A rock whose edges were rounded as it was carried from place to place by running water or glaciers (p. 348)

bronchial (brŏŋ′kĭ ăl) *tube.* One of the parts into which the windpipe divides (p. 437)

bronchitis (brŏn kī′tĭs). An inflammation of the windpipe or its branches (p. 315)

Brontosaurus (brŏn tō sô′ru̦s). A large plant-eating dinosaur, which reached a length of about 65 feet (p. 402)

Bronze Age. A period in the history of man's development, which takes its name from the widespread use of bronze (p. 418)

Bureau of Biological Survey. A bureau of the United States Department of Agriculture (p. 495)

Bureau of Fisheries. A division of the United States Department of Commerce (p. 481)

Byrd, Richard Evelyn (1888–). American rear admiral and explorer, noted especially for his expeditions to the antarctic regions (p. 301)

cactus (kăk'tu̥s) [plural *cacti* (kăk'tī)]. A plant which can live in an extremely dry environment. It has fleshy stems and branches with scales and spines instead of leaves. There are several kinds of cacti (p. 255)

calcium (kăl'sĭ u̥m). An element whose compounds occur in nature; for example, shell and limestone. It is important in bone formation in our bodies (p. 312)

calyx (kā'lĭks). The outer part of a flower, usually green in color (p. 205)

capillary (kăp'ĭ lĕr ĭ). A tiny blood tube with thin walls. Food and gases pass through the walls to and from the body cells. Capillaries connect arteries and veins (p. 439)

carbohydrate (kär bō hī'drāt). Food that is a compound of carbon, hydrogen, and oxygen. Sugar and starches are examples of carbohydrates (p. 425)

carbon (kär'bo̥n). An element which is contained in all living materials. Charcoal, coal, and graphite are forms of carbon (p. 400)

carbon cycle (kär'bo̥n sī'k'l). The chain of events in which the carbon that is part of the carbon dioxide in air becomes part of plant or animal bodies and finally enters the air again as carbon dioxide (p. 422)

carbon dioxide (kär'bo̥n dī ŏk'sīd). One of the gases in the air. It is a nonpoisonous product of respiration and of burning, and is needed by plants for food-making. In solid form it is known as "dry ice" (p. 204)

carbonic (kär bŏn'ĭk) *acid*. The acid formed when carbon dioxide is dissolved in water (p. 341)

Cassiopeia (kăs ĭ ō pē'yḁ). A constellation in the northern sky which looks somewhat like the letter W (p. 12)

Cecropia (sē krō'pĭ ḁ). The largest moth to be found in the eastern United States. It is brown in color with red markings (p. 238)

cell. The smallest complete unit or part of living matter (p. 207). The unit, or room, in a beehive in which the queen bee lays eggs (p. 234)

cellulose (sĕl'ū lōs). A carbohydrate which human beings cannot digest. The solid framework of plants, the woody parts, is largely cellulose (p. 425)

Cenozoic (sē nō zō'ĭk) *era*. The most recent of the five eras into which

geologists divide the earth's history. The Cenozoic era began about 60 million years ago; we are living in it today (p. 406)

centigrade (sĕn'tĭ grād). A thermometer scale which is marked so that there are 100 degrees between the freezing point of water (0° C.) and the boiling point (100° C.) (p. 118)

check dams. Small dams built to slow down running water. They are especially useful in controlling gullies (p. 515)

chemical (kĕm'ĭ kăl). Relating to chemistry, that branch of science which deals with the changing of one substance into another (p. 49)

chlorophyll (klō'rō fĭl). The green coloring matter of plants (p. 204)

chromium (krō'mĭ ụm). A hard metal that does not rust readily. It is used to make alloys and to coat other metals (p. 496)

chrysalis (krĭs'ạ lĭs). The same as pupa. A stage in the life of insects, such as butterflies, through which they pass just before becoming adults (p. 238)

circulatory (sẽr'kū lạ tō rĭ) *system.* The parts of the body through which the blood moves (p. 437)

cirrus (sĭr'ụs) [plural *cirri* (sĭr'ī)]. A filmy white kind of cloud, usually about 20,000 to 40,000 feet above sea level. Cirrus clouds are composed of tiny ice crystals (p. 106)

climate (klī'mĭt). The average weather over a period of years (p. 82)

clinical (klĭn'ĭ kăl) *thermometer.* A thermometer used for taking body temperature (p. 308)

cobalt (kō'bôlt). A chemical element; a tough silver-white metal (p. 49)

comet (kŏm'ĕt). A body which revolves around the sun and is composed mostly of gas (p. 43)

composition (kŏm pō zĭsh'ụn). The materials of which something is made (p. 52)

compound (kŏm'pound). A substance which is formed from at least two elements and which has different properties from each of them (p. 339)

compound bar. A metal bar made of strips of different metals riveted together (p. 120)

concentrated (kŏn'sẹn trāt ĕd) *food.* Food that is high in energy value but contains little cellulose (p. 426)

condensation (kŏn dĕn sā'shụn). The process of changing from a gas to a liquid; for example, water vapor and steam may condense to form water (p. 104)

conduction (kọn dŭk'shụn). The transfer of heat through a substance.

When one end of a piece of metal is held in a flame, for instance, the other end becomes hot because of the conduction of heat (p. 94)

conductor (kọn dŭk′tẽr). A substance that will allow heat or electricity to travel through it; for example, most metals are good conductors of heat (p. 146)

conservation (kŏn sẽr vā′shụn). The protection of our natural wealth from loss or injury (p. 347)

constellation (kŏn stẹ lā′shụn). A group of stars which seem to be together in the sky (p. 10)

contour (kŏn′to͝or) *line.* A line connecting the points on a land surface that have the same elevation (p. 514)

contour plowing. Plowing in which the furrows curve around slopes instead of going up and down hill (p. 514)

convection (kọn vĕk′shụn). The transfer of heat in gases, such as air, and in liquids, such as water, by means of moving currents (p. 95)

Copernicus (kō pẽr′nĭ kụs), *Nicolaus* (1473–1543). A Polish astronomer who first determined by observation and mathematical calculation that the sun was the center of the solar system (p. 32)

coral (kŏr′ạl). A kind of small sea animal. The limestone skeletons of many corals make up a coral reef, which is a ridge built up from the sea bottom to the surface of the sea or just below it (p. 288)

corolla (kō rŏl′ạ). The petals of a flower. The corolla is located inside the calyx (p. 205)

corona (kō rō′nạ). The brilliant rim of light that surrounds the sun. It is seen only during a total eclipse of the sun (p. 69)

Cro-Magnon (krō mȧ nyôɴ′) *man.* One of the early races of man. Cro-Magnon man was tall and erect and was more advanced than Neanderthal man (p. 411)

cross section. A cut made through something, or a picture of such a cut (p. 354)

cross-pollination (krŏs pŏl ĭ nā′shụn). The transfer of pollen from the stamen of one flower to the pistil of another (p. 207)

Culex (kū′lĕks). The kind of mosquito common in the northern part of the United States. It does not carry disease (p. 232)

culture (kŭl′tụ̄r). The stage of civilization in which a group of people lives (p. 413)

culture plate. A plate containing food materials suitable for the growth of bacteria (p. 319)

cumulus (kū′mū lụs) [plural *cumuli* (kū′mū lī)]. A massy white kind of cloud, usually about a mile above sea level. Cumulus clouds appear to be piled up like a mountain (p. 106)

cycle (sī′k'l). A process which is always going on and always being repeated; for example, the cycle of the seasons (p. 220)

cyclone (sī′klōn). A condition of the atmosphere in which winds rotate about a center of low pressure. The word "cyclone" is often wrongly used to mean tornado (p. 136)

delta (dĕl′tạ). Soil laid down at the mouth of any river (p. 351)

dew. Moisture which condenses on objects when their temperature is below that of the surrounding air (p. 106)

dew point. The temperature at which the water vapor in the air begins to change to liquid. The dew point depends on the amount of moisture in the air (p. 126)

diaphragm (dī′ạ frăm). The layer of mụscle tissue dividing the chest cavity from the abdomen (p. 436)

dike (dīk). A mass of igneous rock that flowed into a crack while liquid. A dike cuts across the layers of sedimentary rock around it (p. 382)

dinosaur (dī′nō sôr). A kind of reptile that lived millions of years ago in the Mesozoic era. Dinosaurs varied in length from 2 to 90 feet (p. 278)

Diplodocus (dĭ plŏd′ō kụs). A very large dinosaur, which sometimes reached a length of 80 feet. It fed on plants (p. 405)

drone. A male bee (p. 235)

dry ice. Carbon dioxide in solid form (p. 336)

duct (dŭkt). A tube, especially one which carries a fluid from a gland (p. 443)

Dust Bowl. A large portion of the central United States where the land has been very seriously eroded (p. 512)

Dutch elm disease. A disease of the elm tree which causes the leaves to turn yellow and drop off and the tree to die (p. 492)

earth's crust. The outer portion of the earth, the part on which we live and which we can study by observation (p. 496)

eclipse (ē klĭps′). The blotting out of one of the heavenly bodies, either because it passes into the shadow of another or because another body comes between it and the observer (p. 68)

eelgrass. A plant which grows under water in ponds and streams. It has very long narrow leaves. Its scientific name is *Vallisneria* (văl ĭs nē′rĭ ạ) (p. 282)

egg nucleus (nū′klē ụs). The nucleus within the ovule which unites with the sperm nucleus to form the fertilized egg (p. 207)

electric generator. A machine which produces electric energy (p. 54)

element. A substance composed of only one kind of material. There are 92 known elements, which combine to make all the other substances we know (p. 49)

embryo (ĕm′brĭ ō). The young of a plant or of an animal in its earliest stages of development (p. 208)

energy (ĕn′ẽr jĭ). The ability to move objects. Heat, light, and electricity are forms of energy. Certain foods are especially important in producing energy for the body (p. 24)

environment (ĕn vī′ru̥n mĕ̥nt). The objects and forces around us or around any living thing (p. 192)

equinox (ē′kwĭ nŏks). The time when day and night are of equal length everywhere on earth, that is, about March 21 or September 21. At these times the earth's axis is not tilted either toward or away from the sun (p. 168)

erode (ē rōd′). To wear away. Soil is eroded by the action of running water (p. 345)

erosion (ē rō′zhu̥n). The gradual wearing away of the earth's surface. The loosening and carrying away of rock and soil by wind, water, or ice (p. 345)

Eskimo (ĕs′kĭ mō). A people most of whom live on the arctic coasts of North America (p. 329)

esophagus (ē sŏf′ḁ gu̥s). The gullet; the food tube leading from the mouth to the stomach (p. 431)

excretion (ĕks krē′shu̥n). A waste product given off by a living thing (p. 230)

extract (ĕks trăkt′). To separate or purify. Metals are extracted from their ores (p. 498)

Fahrenheit (făr′e̥n hīt). A thermometer scale which is marked so that there are 180 degrees between the freezing point of water (32° F.) and the boiling point (212° F.) (p. 118)

fault (fôlt). A crack in the earth's crust along which slipping of rock layers has taken place (p. 375)

Fehling's (fā′lĭngz) *solution.* A solution used to test for the presence of glucose and some of the other sugars (p. 446)

fertilization (fẽr tĭ lĭ zā′shu̥n). The union of the egg nucleus and the sperm nucleus to form a fertilized egg, which develops into a new individual (p. 207)

fertilized egg. An egg which will develop into a new plant or animal (p. 208)

fissure (fĭsh'ẽr). A crack in the earth's surface; usually there is a distinct gap between the sides of the fissure (p. 372)

fold. A bend in rock; a buckling of the earth's crust (p. 380)

Forest Service. A bureau of the United States Department of Agriculture (p. 485)

fossil (fŏs'ĭl). Any trace of a plant or animal that lived in a past age. Petrified wood is a well-known kind of fossil (p. 387)

frost. The result of the condensation of water vapor on objects when their temperature is below the freezing point of water (p. 106)

galaxy (găl'ăk sĭ). A group of many millions of stars, of which the sun is one (p. 27)

Galileo (găl ĭ lē'ō) (1564–1642). An outstanding Italian scientist. Among other things, he proved that the planets move around the sun (p. 21)

gaseous (găs'ē u̥s). In the form of a gas. Gaseous substances are able to take the volume and shape of objects into which they are put (p. 422)

gastric (găs'trĭk) *juice.* A fluid produced by the glands in the stomach lining. Gastric juice is necessary for the digestion of proteins (p. 433)

Geological Survey. A division of the United States Department of the Interior (p. 395)

gibbous (gĭb'u̥s). Convex or bulging. Used to describe the phase of the moon between half-moon and full moon (p. 67)

Gila (hē'lḁ) *monster.* A poisonous orange-and-black lizard, sometimes as much as two feet long. It lives in the desert regions of Arizona and New Mexico (p. 266)

gill (gĭl). An organ for breathing under water. Fish and some other water animals have gills (p. 222)

glacial (glā'shăl) *drift.* The loose earth, rocks, and boulders left behind when a glacier melts (p. 361)

Glacial Period. The great Ice Age, which began about a million years ago. Glaciers covered all of what is now Canada and many of the northern states (p. 358)

glacier (glā'shẽr). A mass of slowly moving snow and ice that forms in a region where snowfall exceeds melting (p. 332)

gland. An organ of the body which produces a fluid (p. 266)

glucose (glo͞o'kōs). A simple sugar formed during the digestion of carbohydrates (p. 425)

granite (grăn'ĭt). A coarse igneous rock in which grains of quartz feldspar, and mica may be seen (p. 337)

graphite (grăf'īt). A form of carbon which occurs in nature. It is soft, black, and shiny (p. 400)

grassland (gràs'lănd). A large area of grass-covered ground (p. 183)

gravity (grăv'ĭ tĭ). The force which pulls objects on or near the surface of the earth toward its center. The attraction between the earth and the sun and other heavenly bodies is usually referred to as *gravitation* (p. 38)

grouse [singular and plural]. A game bird (p. 479)

gully (gŭl'ĭ). A rut deepened and widened by rain and running water (p. 478)

guppy (gŭp'ĭ) [plural *guppies*]. A small tropical fish, which does not lay eggs as most fish do, but produces its young alive (p. 227)

gusher (gŭsh'ẽr). An oil well which is out of control (p. 504)

gypsy (jĭp'sĭ) *moth.* A moth whose larva is very destructive to trees (p. 492)

hail. The kind of precipitation resulting when rain passes through a layer of cold air before reaching the earth (p. 106)

Halley's (hăl'ĭz) *comet.* A comet which appears regularly about every seventy-six years. It was last visible in 1910. It is named after an English astronomer, who saw it in 1682 and foretold its return in 1758 (p. 43)

headwaters (hĕd'wô tẽrz). The source of a stream (p. 227)

helium (hē'lĭ ṷm). A colorless gas which is very light in weight and does not burn (p. 392)

hibernation (hī bẽr nā'shṷn). Spending the winter in a state of inactivity (p. 220)

horned toad. A kind of lizard which has hornlike spines. It is adapted to life in desert regions (p. 261)

horse latitudes. The regions about 30 degrees north and 30 degrees south of the equator, where the pressure is high and the atmosphere is calm (p. 101)

humidity (hū mĭd'ĭ tĭ). The amount of water vapor in the air (p. 102)

Huntington, Ellsworth (1876–). An American geologist and geographer, who has studied the effect of climate on man (p. 322)

hurricane. A storm of great violence. The term "hurricane" is used in describing winds of about 100 miles per hour (p. 87)

hydrochloric (hī drō klō'rĭk) *acid.* A compound of hydrogen and chlorine dissolved in water (p. 340)

hydrogen (hī'drō jẹn). A colorless gas, the lightest element known (p. 425)

hydrophobia (hī drō fō′bĭ ạ). An animal disease which may be transmitted to human beings. Hydrophobia, or rabies, is treated by injections of antitoxin (p. 462)

hygrometer (hī grŏm′ē tẽr). An instrument used to measure humidity (p. 131)

Ice Age. A time when glaciers covered much more of the earth's surface than they do today. The last great Ice Age began about a million years ago (p. 358)

igneous (ĭg′nē ụs) *rocks.* Rocks formed when hot molten matter from deep within the earth cools and becomes solid (p. 378)

inclination (ĭn klĭ nā′shụn). The slant of a line or a plane from the vertical or horizontal position; for instance, the tilt of the earth's axis from the vertical (p. 173)

indigestible (ĭn dĭ jĕs′tĭ b'l). Not readily changed from solid to liquid form; not easily absorbed (p. 430)

insect (ĭn′sĕkt). An animal with three separate body parts and six legs (p. 179)

interglacial (ĭn tẽr glā′shạl) *periods.* The intervals between the advances of the glaciers. There were three interglacial periods during the Ice Age (p. 408)

intestine. Part of the digestive system. Digestion takes place largely in the small intestine; wastes are stored in the large intestine (p. 318)

isobar (ī′sō bär). A solid line on a weather map, drawn so as to connect places having the same air pressure at a given time (p. 138)

isotherm (ī′sō thẽrm). A dotted line on a weather map, drawn so as to connect places having the same temperature at a given time (p. 138)

Japanese beetle. A small green-and-brown beetle, a serious and destructive pest. The adults feed upon leaves and fruit; the larvae eat grass roots (p. 237)

Java (jä′vạ) *man.* One of the earliest of human beings, who probably lived even before the Ice Age. The fossils of the Java man date back about a million years (p. 409)

Joshua (jŏsh′ū ạ) *tree.* A branched yucca, often 25 feet high. The flowers are greenish-white and grow in clusters (p. 261)

Jupiter (jōō′pĭ tẽr). The largest of the planets, more than five times as far from the sun as the earth is. Jupiter has eleven moons (p. 21)

Kepler (kĕp′lẽr), *Johannes* (1571–1630). A German astronomer, who showed that the orbits of the planets are not exactly circles (p. 32)
kidney (kĭd′nĭ). A gland which removes waste products from the blood. The kidneys are situated near the spinal column (p. 444)
kilogram (kĭl′ō grăm). A unit of weight, about 2.2 pounds (p. 452)
kilogram-calorie (kĭl′ō grăm kăl′ō rĭ). The amount of heat needed to raise the temperature of one kilogram of water 1° C. (p. 451)

ladybird beetle. A beetle which destroys many insects harmful to plants. It is usually brightly colored, and is sometimes called the ladybug (p. 233)
landlocked. Enclosed, or nearly enclosed, by land (p. 294)
larva (lär′va̤) [plural *larvae* (lär′vē)]. The second stage in the life of insects, during which they eat large amounts of food. Larvae are often wormlike, and some are called caterpillars (p. 228)
latitude (lăt′ĭ tūd). An imaginary line on the earth's surface, parallel to the equator and used to indicate distance north or south of the equator (p. 10)
lava (lä′va̤). Igneous rock which cooled down from the liquid state at the surface of the earth. The rock which pours forth from a volcano is molten lava (p. 366)
leech (lēch). A kind of blood-sucking worm (p. 264)
life cycle. The complete life of an organism from its beginning until its death (p. 220)
light-year. The distance light travels in a year. As the speed of light is about 186,000 miles per second, a light-year is about 6 trillion miles (p. 24)
lime (līm). A compound of calcium and oxygen (p. 342)
limestone (līm′stōn). A sedimentary rock consisting of calcium, carbon, and oxygen (p. 288)
limewater (līm′wô tẽr). Water in which lime has been dissolved (p. 444)
Little Dipper. The constellation that includes the North Star. It is sometimes called the Little Bear or Ursa Minor (p. 12)
liver. A very large organ situated near the stomach. It makes bile, which helps to dissolve fat (p. 431)
lunar (lū′nẽr). Having to do with the moon (p. 76)
lupine (lū′pĭn). A plant which grows in many parts of the country. It belongs to the same group as the bean plant, and bears white, yellow, or blue flowers (p. 261)
lymph (lĭmf). A nearly colorless liquid which seeps through the walls of the capillaries and bathes the body cells (p. 441)

Machine Age. A period in man's culture which is so called from the widespread use of machines (p. 500)

maggot (măg'u̥t). The larva of a fly, living in decaying matter (p. 228)

malaria (ma̤ lâr'ĭ a̤). A disease caused by microscopic animals in the blood. Malaria is transmitted to man by the bite of the *Anopheles* mosquito (p. 232)

mammal (măm'ăl). A kind of animal that feeds its young with milk (p. 406)

mammoth (măm'u̥th). An extinct animal, resembling the elephant (p. 411)

Maori (mä'ō rĭ). One of the native people who inhabited New Zealand (p. 329)

marine (ma̤ rēn'). Concerned with the sea. Marine plants and animals are those living in the ocean (p. 480)

marmot (mär'mu̥t). A small animal with coarse hair; a kind of woodchuck (p. 245)

Mars (märz). A planet which is recognized by the redness of its light. It is about 141 million miles from the sun (p. 39)

Martian (mär'shĭ ăn). Having to do with the planet Mars (p. 40)

Mauna Loa (mou'nä lō'ä). A volcano in Hawaii National Park (p. 371)

Mercury (mẽr'kū rĭ). The smallest planet in the solar system. Mercury is the planet closest to the sun (p. 36)

mercury. One of the elements; a silvery metal, which is liquid at room temperature (p. 116)

Mesozoic (mĕs ō zō'ĭk) *era.* The geologic era which came just before the Cenozoic, or most recent, era. The Mesozoic era began about 200 million years ago and ended about 60 million years ago. It is often called the Age of Reptiles (p. 403)

mesquite (mĕs kēt'). A desert shrub, having fragrant flowers and beanlike pods rich in sugar (p. 261)

metallurgy (mĕt''l ẽr jĭ). The science of extracting metals from their ores (p. 498)

meteor (mē'tē ẽr). A particle of matter which has entered the earth's atmosphere from distant space. When meteors strike the air, they are heated by the resistance the air offers to their movement. We then see them as "shooting stars" (p. 46)

meteorite (mē'tē ẽr īt). That portion of a meteor which reaches the earth's surface (p. 47)

meteorology (mē tē ẽr ŏl'ō jĭ). The science of the weather (p. 324)

Michelson (Mī'kĕl su̥n), *Albert* (1852–1931). A famous American

scientist, who made accurate measurements of the speed of light and measured the diameters of stars (p. 24)

migrate (mī′grāt). To travel regularly from one region to another for feeding or breeding. Migration usually depends upon the season (p. 240)

mineral (mĭn′ẽr ăl). A substance which has a definite chemical composition and is found in the earth's crust (p. 199)

mineral salts. Compounds of a metal with other elements (p. 407)

mineralogy (mĭn ẽr ăl′ō jĭ). The study of the minerals (p. 519)

Mount Etna. A volcano in Sicily, the island off the southern end of Italy (p. 369)

Mount Lassen. An active volcano in northern California (p. 370)

National Park Service. A division of the United States Department of the Interior (p. 495)

Neanderthal (nā än′dẽr täl) *man*. One of the earlier races of man, who lived in Europe during the third interglacial period, that is, just before the most recent advance of the ice (p. 410)

nebula (nĕb′ū la̤) [plural *nebulae* (nĕb′ū lē)]. Most nebulae are vast collections of stars. They are so far from us that they appear hazy even through powerful telescopes (p. 28)

nectar (nĕk′tẽr). A sweet liquid produced by flowers, from which bees make honey (p. 206)

Neolithic (nē ō lĭth′ĭk) *Age*. The New Stone Age, or the period in which primitive man made polished stone instruments (p. 411)

Neptune (nĕp′tūn). The third largest of the planets. Neptune is so far away that it cannot be seen without a telescope (p. 42)

nervous (nẽr′vu̥s) *system*. The network of nerves spreading to all parts of the body and connected with the brain (p. 455)

Newton, Sir Isaac (1642–1727). An English scientist who explained the motions of the stars and planets (p. 32)

nimbus (nĭm′bu̥s). A rain cloud, or thunder cloud. Nimbus clouds are large and gray (p. 106)

nitrogen (nī′trō jĕn). A gaseous element which makes up about four fifths of the air and is present in all living things (p. 428)

nucleus (nū′klē u̥s). The central part of a thing. In biology the nucleus is the portion of the cell which controls the cells' growth and reproduction (p. 207)

observatory (o̥b zẽr′va̤ tō rĭ). A building arranged and equipped for the use of astronomers in studying the heavens (p. 20)

ocotillo (ō kō tēl′yō). A thorny desert plant, which bears scarlet flowers (p. 259)

octopus (ŏk′tō pu̥s). A sea animal with eight long arms covered with suckers. There are many kinds of octopuses, the most common of which is the devilfish (p. 294)

orbit (ôr′bĭt). The path in which a body moves as it goes around another body; for example, the path of a planet around the sun is its orbit (p. 34)

ore. A mineral from which a metal may be profitably extracted (p. 496)

ovary (ō′va̤ rĭ). In plants the enlarged hollow portion at the base of the pistil in which the seeds develop. In animals the organ in which the eggs are produced (p. 207)

ovule (ō′vūl). The egg cell of a plant which develops into the seed after its nucleus unites with a sperm nucleus (p. 207)

oxygen (ŏk′sĭ je̥n). A colorless gas, the most abundant of all the elements. All animals need oxygen for breathing. It makes up about one fifth of the air; air is present in running water (p. 226)

Paleolithic (pā lē ō lĭth′ĭk) *Age.* The Old Stone Age, the period in which primitive man made crudely chipped stone tools (p. 411)

Paleozoic (pā lē ō zō′ĭk) *era.* The middle one of the five great eras into which geologists divide earth history. It began about 540 million years ago and ended about 200 million years ago (p. 400)

pancreas (păn′krē ăs). A large gland located just below the stomach. It produces a fluid which helps to dissolve foods (p. 431)

pancreatic (păŋ krē ăt′ĭk) *juice.* The clear solution made in the pancreas; it is poured into the small intestine, where it acts on the food already acted upon by the gastric juice (p. 434)

passenger pigeon (păs′e̥n jẽr pĭj′u̥n). A North American wild pigeon which once was very abundant but is now extinct (p. 479)

Peary, Robert E. (1856–1920). American admiral and arctic explorer (p. 31)

Pegasus (pĕg′a̤ su̥s). A constellation in the northern sky (p. 12)

Peking (pē′kĭng′) *man.* One of the earliest of the human race. The fossils of the Peking man date back about a million years, to a time before the glacial period (p. 409)

penguin (pĕn′gwĭn). A short-legged water bird which lives in antarctic regions. Penguins cannot fly, but are powerful swimmers (p. 274)

pepsin (pĕp′sĭn). A complex chemical substance made by the glands in the stomach. Pepsin starts the digestion of proteins (p. 433)

periwinkle (pĕr'ĭ wĭŋ k'l). A small sea snail (p. 280)
perpendicularly (pēr pĕn dĭk'ū lēr lĭ). Straight up and down; at right angles to a line or surface (p. 163)
phase (fāz). One of the different shapes in which the lighted side of the moon or a planet appears to us (p. 65)
phosphorus (fŏs'fō rus̱). An element which burns at a very low temperature. Proteins contain phosphorus (p. 428)
photosynthesis (fō tō sĭn'thē sĭs). The process by which plants build sugars and starches from water and carbon dioxide in the presence of chlorophyll and sunlight (p. 204)
physiology (fĭz ĭ ŏl'ō jĭ). The study of the way the body works during life (p. 446)
Piltdown (pĭlt'doun) *man*. One of the earlier races of man. Piltdown man lived in England hundreds of thousands of years ago (p. 409)
pistil (pĭs'tĭl). An organ in the center of the flower; it receives the pollen and later contains the developing seeds (p. 205)
plane. A level surface, not curved (p. 71)
planet (plăn'ĕt). A body, like the earth, which revolves about the sun and reflects the sun's light (p. 8)
planetoid (plăn'ĕt oid). A body similar to a planet but much smaller. There are at least a thousand planetoids, which revolve around the sun in an orbit between that of Mars and that of Jupiter. Planetoids are sometimes called asteroids (p. 46)
Pleiades (plē'ya̱ dēz). A constellation in which six stars are visible to most people, but which is seen to contain at least one hundred when viewed through a telescope (p. 12)
Pluto (plōō'tō). The planet which is farthest from the sun of all those known. Pluto was discovered in 1930 (p. 42)
pod (pŏd). The fruit of plants such as the bean. Pods are dry rather than moist (p. 207)
pollen (pŏl'e̱n). The fine yellow "dust" produced by flowers. It is necessary in the formation of seeds (p. 206)
pollen cup. A part of the flower located at the end of each stamen, in which pollen is produced (p. 206)
pollen tube. A tube formed when pollen grains are deposited on the stigma. It grows downward into the seed pod, where it penetrates the ovules (p. 207)
pollinate (pŏl'ĭ nāt). To transfer pollen from the stigma to the pistil (p. 233)
pollution (po̱ lū'shu̱n). Making impure or unclean (p. 483)
prawn (prôn). An edible, shrimplike sea animal (p. 282)

praying mantis. An insect which eats other insects. It gets its name from the position it takes while waiting for its victims (p. 233)
precipitation (prē sĭp ĭ tā'shu̥n). The falling of rain, snow, mist, hail, or sleet (p. 103)
protein (prō'tē ĭn). A complex substance which always contains nitrogen and which is a part of all living things. Some foods are especially rich in proteins (p. 428)
Proterozoic (prŏt ēr ō zō'ĭk) *era.* The geologic era which came just after the Archeozoic, or earliest, era of the earth's history. It ended about 540 million years ago (p. 400)
pulmotor (pŭl'mō tēr). An apparatus for pumping air or oxygen in and out of the lungs of a suffocated person (p. 446)
pupa (pū'pa̱) [plural *pupae* (pū'pē)]. The third stage in the life of some insects, during which they are very inactive. Cocoons contain and protect pupae (p. 229)

quinine (kwī'nīn). A drug obtained from the bark of certain South American trees; it is useful in the treatment of malaria (p. 462)

radiant (rā'dĭ ănt) *energy.* A form of energy which travels in straight lines, or rays, through empty space. When these rays strike a substance, the energy is absorbed and is changed to heat energy (p. 54)
radiation (rā dĭ ā'shu̥n). The process by which energy is sent through space (p. 53)
radium (rā'dĭ u̥m). An element which gives off radiant energy (p. 392)
rain forest. The type of plant life found where rain is abundant and the temperature is high (p. 179)
rain gauge (gāj). An instrument for measuring the amount of rainfall (p. 88)
relative humidity (hū mĭd'ĭ tĭ). The relation between the amount of water vapor in the air and the amount that the air can hold at the same temperature (p. 127)
reproduction (rē prō dŭk'shu̥n). The process by which plants and animals give rise to offspring (p. 228)
resistance (rē zĭs'tăns). The power to repel disease (p. 312)
resources (rē sōrs'ĕz). Materials such as mineral deposits, forests, and water power (p. 482)
respiratory (rē spīr'a̱ tō rĭ) *system.* The parts of an organism by which oxygen is taken in and carbon dioxide given off (p. 437)
revolution. The act of going around in an orbit, used especially of the earth's travels around the sun (p. 38)

rhododendron (rō dō dĕn′drọn). A shrub that grows chiefly in mountainous regions. The plants have handsome white, pink, or purple flowers (p. 255)

rockweed. A coarse seaweed growing attached to rocks (p. 280)

rodent. A gnawing animal. Rats, squirrels, rabbits, and porcupines are rodents (p. 264)

Römer (rē′mẽr) *Olaus* (1644–1710). A Danish astronomer, the first person to determine the speed of light (p. 24)

root hairs. A fuzzy growth on rootlets. Water and dissolved minerals enter the plant through the root hairs (p. 202)

rotation. Act of turning around; used especially of the turning of the earth on its axis (p. 38)

roughage (rŭf′ĭj). Coarse food; food containing a large proportion of cellulose (p. 426)

runoff (rŭn′ôf). The water which is removed from soil (p. 514)

saber-toothed (sā′bẽr to͞otht) *tiger.* An extinct kind of tiger, having a pair of large curved teeth (p. 411)

saguaro (sạ gwä′rō). A cactus which grows as much as 60 feet high. The blossom is the state flower of Arizona (p. 255)

salamander (săl′ạ măn dẽr). An amphibian which looks somewhat like a lizard but has no scales (p. 225)

saliva (sạ lī′vạ). The liquid in the mouth which, when mixed with food, changes starch into glucose (p. 432)

salivary (săl′ĭ vĕr ĭ) *glands.* The glands which manufacture saliva and empty it into the mouth (p. 431)

sand dollar. A flat, circular sea animal having a thin, brittle shell (p. 282)

sand hopper. A tiny crablike animal living on beaches. Sand hoppers are often called beach fleas (p. 282)

sand-blasting. A process in which sand is blown against hard surfaces to clean or polish them. Streams of air or steam are used to direct the sand (p. 342)

sandstone. A sedimentary rock composed of sand grains cemented together (p. 384)

Sargasso (sär găs′ō) *Sea.* A large area of comparatively still water in the north Atlantic Ocean. Seaweed floats to this region from the shores of the Gulf of Mexico and the Caribbean Sea, and remains there because there are no strong ocean currents flowing outward from it (p. 291)

sargassum (sär găs′ụm). A kind of seaweed occurring in the warmer parts of the Atlantic Ocean (p. 293)

satellite (săt'ḛ līt). A heavenly body revolving around another, usually a body revolving about a planet (p. 60)

Saturn (săt'ẽrn). The second largest planet. Rings of solid matter, as well as moons, revolve around it (p. 41)

scallop (skŏl'ụp). A shellfish. As its name suggests, the edges of the shell are wavy, or scalloped (p. 282)

scorpion (skôr'pĭ ụn). An animal somewhat similar to the spider. It has a narrow tail which bears a poisonous sting (p. 264)

Scott, Robert F. (1868–1912). English captain and antarctic explorer (p. 302)

sea anemone (ạ nĕm'ō nē). A delicate sea animal. It gets its food and protects itself by means of hairlike cells, which give it the appearance of a plant (p. 280)

sea horse. A small fish found in most warm seas. Its head looks something like that of a horse (p. 294)

sedge (sĕj). A grasslike plant which often grows in bunches in swampy places (p. 214)

sediment (sĕd'ĭ mḛnt). Solid particles which settle out of water (p. 352)

sedimentary (sĕd ĭ mĕn'tạ rĭ) *rock.* Rock formed by the cementing together of sediment (p. 378)

seed coat. The outside covering of a seed (p. 208)

seismograph (sīz'mō̤ gråf). An instrument which detects and records earthquakes, even when they are very slight or very far away (p. 374)

sequoia (sē kwoi'ạ). An evergreen tree that reaches a height of more than 300 feet. The two kinds of sequoias are the giant sequoia and the redwood (p. 407)

shad. A food fish of the north Atlantic coast (p. 479)

shale (shāl). A sedimentary rock formed from fine bits of mud or clay (p. 337)

shellfish. A water animal having a shell, as an oyster or a clam (p. 277)

Shetland (shĕt'lănd) *pony.* A small, stocky breed of horse (p. 406)

silica (sĭl'ĭ kạ). A compound containing oxygen and the element silicon. The sand of the seashore is a variety of silica (p. 321)

sill. A mass of igneous rock which has flowed between layers of sedimentary rock (p. 383)

sinus (sī'nụs). An opening in a bone of the skull which contains air and connects with the nostrils. There are four sinuses (p. 315)

smoke tree. A shrub which bears many clusters of tiny flowers (p. 261)

snow. The form of precipitation resulting when the air in a given region is below the freezing point of water (p. 106)

social (sō′shăl) *insects.* Insects which live together in more or less organized communities (p. 234)

sodium chloride (sō′dĭ u̦m klō′rīd). The chemical name for common salt (p. 339)

soil. Bits of crumbled rocks and decayed vegetable or animal materials which together make up the top layer of the earth (p. 345)

Soil Conservation Service. A division of the United States Department of Agriculture (p. 516)

solar (sō′lẽr). Having to do with the sun (p. 33)

soluble (sŏl′ū b′l). Able to dissolve. Sugar is soluble in water (p. 339)

solution (sō lū′shu̦n). A substance dissolved in another, usually a liquid (p. 339)

Spanish bayonet. A desert plant with rigid spine-tipped leaves; a kind of yucca (p. 261)

species (spē′shĭz, plural spē′shēz). A distinct kind of animal or plant (p. 485)

spectroscope (spĕk′trō skōp). An instrument used to determine the elements of which things are made. The spectroscope is used in studying the composition of the heavenly bodies (p. 52)

sperm. A kind of cell which fertilizes an egg cell, so that a new organism may be produced (p. 221)

spleen (splēn). An organ lying near the stomach. It stores blood when the body is not very active and releases it when it is needed (p. 453)

sponge (spŭnj). A sea animal which grows in a plantlike fashion. Its skeleton can absorb large amounts of water when wet without losing its toughness (p. 288)

stalactite (sta̦ lăk′tīt). Limestone hanging like an icicle from the roof or sides of a cavern (p. 341)

stalagmite (sta̦ lăg′mīt). A spike of limestone (like a stalactite turned upside down) formed on the floor of a limestone cave by drippings from the roof (p. 341)

stamen (stā′me̦n). An organ near the center of the flower; it produces the pollen (p. 205)

star. A heavenly body, other than comets and meteors, which shines by its own light (p. 6)

Stegosaurus (stĕg ō sô′ru̦s). A large dinosaur, which had a ridge of horny plates along its back (p. 405)

stigma (stĭg′ma̦). The sticky end of the pistil, on which pollen is deposited (p. 207)

stoma (stō′ma̦) [plural *stomata* (stō′ma̦ ta̦)]. A tiny opening in the

surface of a leaf. Carbon dioxide enters leaves through their stomata, and water vapor and oxygen are given off (p. 204)

Stone Age. The first known period of human culture, when men made stone tools. The Stone Age is divided into two parts: the Old Stone Age, which is called the Paleolithic; and the New Stone Age, called the Neolithic (p. 411)

stratosphere (strā'tō sfēr). The upper portion of the atmosphere, where there are no clouds (p. 90)

strip cropping. The planting of rows of close-growing crops in between the rows of open-growing crops (p. 514)

Stromboli (strōm'bō lē). An island off the Italian coast, having an active volcano (p. 370)

sturgeon (stûr'jụn). A large food fish whose eggs are made into caviar (p. 480)

sucrose (sū'krōs). The chemical name for common sugar from sugar cane or sugar beets (p. 425)

sulfur (sŭl'fēr). A yellow element. Sulfur is a part of protein foods (p. 428)

sun. The star nearest the earth. The sun is a star of average size and brightness (p. 7)

sunspot. A dark spot on the surface of the sun, usually seen only through a telescope. Sunspots are numerous sometimes and scarce at other times (p. 52)

swordtail. A Central American fish, which does not lay eggs but produces its young alive (p. 227)

talus (tā'lụs). The loose and broken rock at the foot of a cliff (p. 336)

tarantula (tạ răn'tū̮ lạ). A large spider having a poisonous bite, which, however, is not deadly (p. 266)

tentacle (tĕn'tạ k'l). A threadlike organ of touch in some animals (p. 287)

terracing (tĕr'ĭs ĭng). Building steplike banks of soil along the contour lines of sloping land. Terracing lessens erosion (p. 515)

tetanus (tĕt'ạ nụs). A disease caused by a toxin. In tetanus the muscles become rigid (p. 462)

thermograph (thēr'mō grăf). A thermometer which automatically records the temperature (p. 120)

tidal bore. A very high and rapid wave of water resulting in places where the rising tide is hindered by a rapidly narrowing inlet or channel (p. 74)

topsoil (tŏp'soil). The surface soil (p. 347)

tornado (tôr nā′dō). A violent and destructive windstorm. A rapid whirling wind which travels in a narrow path and is accompanied by a funnel-shaped cloud (p. 87)

toxin (tŏk′sĭn). A poison produced by certain bacteria (p. 316)

toxin-antitoxin. A mixture of toxin with enough antitoxin to make it almost ineffective. There is less danger from toxin-antitoxin than from toxin alone (p. 462)

trade winds. Winds that blow toward the equator from the horse latitudes (p. 101)

Triceratops (trī sĕr′a̤ tŏps). A kind of dinosaur that had three horns and a large shield covering the neck (p. 403)

trilobite (trī′lō bīt). A fossil sea animal. Trilobites lived in the Paleozoic era and were the ancestors of lobsters and crabs (p. 400)

tropic of Cancer. The parallel of latitude $23\frac{1}{2}$ degrees north of the equator (p. 174)

tropic of Capricorn. The parallel of latitude $23\frac{1}{2}$ degrees south of the equator (p. 174)

troposphere (trŏp′ō sfēr). The portion of the atmosphere below the stratosphere; the lower air where the weather is always changing (p. 92)

tuber (tū′bẽr). A thickened part of a stem, usually underground, bearing buds which we call "eyes." White potatoes are tubers (p. 216)

tundra (to͝on′dra̤). A treeless plain in a region where the climate is very cold (p. 186)

typhoid (tī′foid) *fever*. A disease caused by bacteria taken into the body in food or drinking water (p. 230)

typhoon (tī fo͞on′). A tropical hurricane occurring in the seas near China and the Philippines (p. 157)

Tyrannosaurus (tĭ răn ō sô′ru̥s). A flesh-eating dinosaur about 45 feet long and 20 feet high (p. 405)

universe (ū′nĭ vẽrs). An enormous group of stars. What we call our sun is a star in one such group (p. 27)

uranium (ū rā′nĭ u̥m). A rare element, which breaks down, passing through many stages until helium and lead result (p. 392)

Uranus (ū′ra̤ nu̥s). A planet much larger than the earth and nearly 1,800,000,000 miles from the sun (p. 42)

urine (ū′rĭn). The liquid waste of the body, removed from the blood by the kidneys (p. 444)

Vega (vē′ga̤). A brilliant, bluish-white star (p. 12)

vein (vān). Any of the blood vessels which carry blood to the heart (p. 436)
velocity (vē lŏs'ĭ tĭ). Rate of motion in a given direction (p. 86)
Venus (vē'nųs). A planet which is not much smaller than the earth, nor much closer to the sun. It has a dense atmosphere which probably contains very little oxygen (p. 39)
verbena (vẽr bē'nạ). A plant with large, fragrant flowers (p. 261)
vernal (vẽr'năl). Occurring in the spring of the year (p. 168)
Vesuvius (vē sū'vĭ ųs). A volcanic mountain in Italy (p. 366)
vibration (vī brā'shųn). Motion back and forth (p. 376)
villus (vĭl'ųs) [plural *villi* (vĭl'ī)]. A tiny finger-like structure on the inner wall of the small intestine. Digestive food passes into the blood stream through the villi (p. 434)
volcano. A mountain from which molten rock and steam are occasionally thrown out from the interior of the earth (p. 61)

water vapor. Water in the form of a gas. Usually the phrase means water vapor at a temperature less than the boiling point, but sometimes it is used to mean steam (p. 444)
waterspout. A storm at sea similar to a tornado. A waterspout results when a rapidly whirling column of air tears up water from the ocean (p. 151)
weather. The state of the atmosphere: its temperature, pressure, moisture, and so on (p. 84)
Weather Bureau. A division of the United States Department of Agriculture which maintains many stations for collecting information about weather (p. 85)
weathering. The wearing away of rocks exposed to the air (p. 509)
westerly wind. A wind blowing from the west. The general movement of the air in the temperate zones is from west to east, and these zones are said to be in the belt of prevailing westerlies (p. 101)
wet-bulb thermometer. A thermometer with a wet cloth around the bulb. When the reading of this thermometer is compared with the reading of an ordinary thermometer, the relative humidity may be calculated (p. 128)
wind gauge (gāj). An instrument for determining wind velocity (p. 85)

yucca (yŭk'ạ). A desert plant which has a cluster of white flowers on a tall stalk (p. 270)

zenith (zē'nĭth). The highest point in the heavens, the point directly overhead (p. 178)

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